

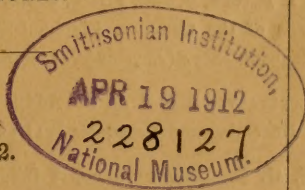
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PROCEEDINGS
OF THE
GENERAL MEETINGS FOR SCIENTIFIC BUSINESS
OF THE
ZOOLOGICAL SOCIETY
OF LONDON.
1912.

PART I.

CONTAINING PAGES 1 TO 240, WITH 32 PLATES
AND 32 TEXT-FIGURES.

MARCH 1912.



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PROCEEDINGS
OF THE
GENERAL MEETINGS FOR SCIENTIFIC BUSINESS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.

EXHIBITIONS AND NOTICES.

October 24, 1911.

Sir JOHN ROSE BRADFORD, K.C.M.G., M.D., F.R.S.,
Vice-President, in the Chair.

THE SECRETARY read the following report on the Additions that had been made to the Society's Menagerie during the months of June, July, August, and September, 1911:—

JUNE.

The registered additions to the Society's Menagerie during the month of June were 602 in number. Of these 164 were acquired by presentation, 70 by purchase, 265 were received on deposit, 32 in exchange, and 71 were born in the Gardens.

The number of departures during the same period, by death and removals, was 328.

Amongst the additions special attention may be directed to:—

A collection of Mammals, Birds, and Reptiles from Africa (chiefly South), presented to H.M. King George by various donors, and deposited in the Gardens by His Majesty on June 2nd, including 2 Eastern White Pelicans (*Pelecanus roseus*), 3 Cape Gannets (*Sula capensis*), 1 Scarce Duck (*Anas sparsa*), 1 Robust Lizard (*Gerrhosaurus validus*), and 1 Black-lined Lizard (*Gerrhosaurus nigro-lineatus*), all new to the Collection.

2 Capped Langurs (*Semnopithecus pileatus*) from the Himalayas, new to the Collection, purchased on June 6th.

1 Hoffmann's Two-toed Sloth (*Chalcepus hoffmanni*), from Brazil, purchased on June 17th.

A collection of rare Indian Birds presented by E. J. Brook, Esq., F.Z.S., on June 6th and 19th, including 2 Grey-headed Ouzels (*Merula castanea*), 2 Pied Bush-Chats (*Pratincola caprata*), 1 Ruby-throat (*Calliope camtschatkensis*), 1 Elegant Bunting (*Emberiza elegans*), 1 Jerdon's Accentor (*Tharrhaleus jerdoni*), 2 Yellow-cheeked Tits (*Machlolophus xanthogenys*), 2 Chestnut-bellied Nuthatches (*Sitta castaneiventris*), 1 Black-headed Wagtail (*Motacilla feldeggii*), 1 Blue-throated Flycatcher (*Cyornis rubeculoides*), 2 Sikkim Siskins (*Chrysomitris tibetana*), 1 Collared Scops Owl (*Scops bakkamæna*), and a pair of Blood Pheasants (*Ithagene cruentus*), all new to the Collection.

2 Peale's Parrot-Finches (*Erythrura pealei*), from the Fiji Islands, new to the Collection, deposited on June 14th.

2 Taviuni Parrakeets (*Pyrrhuloxia taviunensis*), from Taviuni, Fiji Islands, new to the Collection, presented by Dr. P. H. Bahr, F.Z.S., on June 6th.

1 Pigmy Crane (*Porzana pusilla*), and 3 Little Stints (*Tringa minuta*), from India, new to the Collection, deposited on June 6th.

2 Hooded Cranes (*Grus monachus*), from Japan, purchased on June 6th.

JULY.

The registered additions to the Society's Menagerie during the month of July were 444 in number. Of these 174 were acquired by presentation, 62 by purchase, 56 were received on deposit, 12 in exchange, and 140 were born in the Gardens.

The number of departures during the same period, by death and removals, was 278.

Amongst the additions special attention may be directed to:—

1 African Cheetah (*Cynaelurus jubatus*), from Berbera, Somaliland, purchased on July 22nd.

3 Cape Sea-Lions (*Otaria pusilla*), from South Africa, received from Dr. Louis Péringuey, F.Z.S., for H.M. THE KING'S African Collection, on July 29th.

1 Tibetan Wild Ass or Kiang (*Equus kiang*), ♂, born in the Menagerie on July 13th.

7 White-rumped Lories (*Eos fuscata*), from New Guinea, new to the Collection, 1 purchased and 6 deposited on July 13th.

1 Wolf-Snake (*Coluber vulpinus*), from North America, new to the Collection, received in exchange on July 8th.

A Collection of rare Reptiles and Batrachians from Trinidad, presented by Dr. Lewis Henry Gough on July 11th, including 18 Warty Tree-Frogs (*Hyla venulosa*), 1 Daudin's Tree-Frog (*Hyla rubra*), and 16 Tree-Frogs (*Hyla goughi*), all new to the Collection.

AUGUST.

The registered additions to the Society's Menagerie during the month of August were 229 in number. Of these 85 were acquired by presentation, 21 by purchase, 8 were received on deposit, 62 in exchange, and 53 were born in the Gardens.

The number of departures during the same period, by death and removals, was 244.

Amongst the additions special attention may be directed to:—

1 Red-faced Spider-Monkey (*Ateles paniscus*) and 1 Brown Capuchin (*Cebus fatuellus*), from British Guiana, presented by Messrs. John Reed and W. A. Boyd on August 3rd.

1 Clouded Tiger (*Felis nebulosa*), from British North Borneo, presented by Almeric Paget, Esq., F.Z.S., on August 29th.

1 Ocelot (*Felis pardalis*), from Para, presented by F. J. Weldon Taylor, Esq., on August 16th.

1 Lesser Superb Bird-of-Paradise (*Lophorhina minor*), from S.E. New Guinea, new to the Collection, presented by E. J. Brook, Esq., F.Z.S., on August 12th.

1 Red-crested Touracon (*Turacus erythrolophus*), from Angola, deposited on August 31st.

A Collection of American Birds, including 2 Bendire Thrashers (*Torostoma bendirei*), 4 Gila Woodpeckers (*Melanerpes uropygialis*), and 4 Douglas' Quails (*Lophortyx douglasi*), all new to the Collection, received in exchange on August 3rd.

2 Broad-tailed Babblers (*Crateropus platycercus*), from Gambia, new to the Collection, presented by Dr. E. Hopkinson, D.S.O., F.Z.S., on August 7th.

1 Striped Gonatode (*Gonatodes vittatus*), from Trinidad, new to the Collection, presented by Dr. L. H. Gough on August 31st.

SEPTEMBER.

The registered additions to the Society's Menagerie during the month of September were 361 in number. Of these 137 were acquired by presentation, 39 by purchase, 39 were received on deposit, 125 in exchange, and 21 were born in the Gardens.

The number of departures during the same period, by death and removals, was 254.

Amongst the additions special attention may be directed to:—

1 Persian Gazelle (*Gazella subgutturosa*), from Arabia, presented by Rear-Admiral Sir E. J. W. Slade, K.C.I.E., M.V.O., R.N., F.Z.S., on September 7th.

2 Tamaulipas Tawny Thrushes (*Merula tamaulipensis*), 2 Derby Tyrants (*Pitangus derbianus*), 1 Giraud Tyrant (*Myiozetetes similis*), 4 Black-breasted Colins (*Colinus pectoralis*), from Mexico; 4 American Barn-Owls (*Asio accipitrinus*), from North America, 1 Hodgson's Pipit (*Anthus rosaceus*), 1 Indian Tree-Pipit (*Anthus maculatus*), 2 Grey-headed Buntings (*Emberiza fucata*), 1 Pine-Bunting (*Emberiza leucocephala*), and 1 Hume's Short-toed Lark (*Calandrella acutirostris*), from India, all new to the Collection, and received in exchange on September 27th.

2 Formosan Pheasants (*Phasianus formosanus*), from Formosa, new to the Collection, presented by W. H. St. Quintin, Esq., F.Z.S., on September 12th.

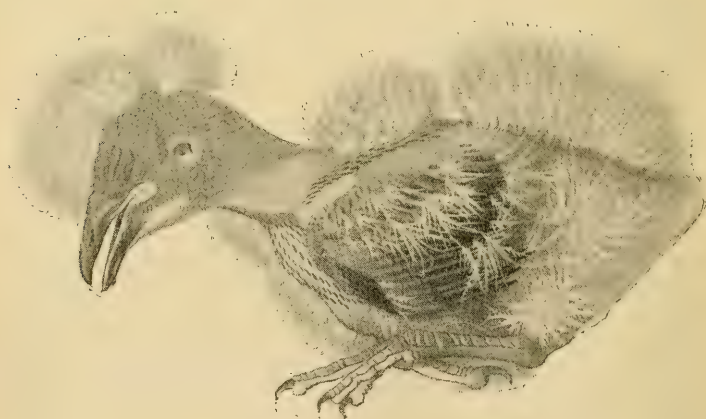
Mr. JAMES DUNBAR-BRUNTON sent for exhibition two skins and a mounted skull, with horns, of Bushbuck shot by him in North-East Rhodesia.

Mr. W. B. COTTON, of the Indian Civil Service, exhibited a number of heads and horns of various species of Gazelles which he had obtained in the Eastern Sudan, and gave a brief account of their habits and distribution. The specimens included *Gazella isabella*, from the hills behind Suakin and the route from Sinkat to Kassala, and eleven specimens, of which he understood nine to be *Gazella tilonura* and two to be *Gazella rufifrons*, from the Atbara, Settit, and Rahad.

Mr. Cotton mentioned that some sportsmen believed *isabella* to be identical with *dorcas*, and advanced a decided opinion that *tilonura* was merely a local form of *rufifrons*. This opinion was fortified by consideration of the extreme variation of type in the specimens exhibited, of which all but one had come from the same locality, namely the Atbara and Settit.

Mr. D. SETH-SMITH, F.Z.S., Curator of Birds, exhibited a spirit-specimen of a nestling Australian Regent-Bird (*Sericulus melinus*) (text-fig. 1), which had been hatched in the aviary of Mr. Reginald Phillipps, of 26 Cromwell Grove, West Kensington, during the past summer. The male parent of this bird was also bred in the same aviary in 1906, and is the only specimen of this fine Bower-Bird ever bred and reared to maturity in captivity.

Text-fig. 1.



Sericulus melinus, ten days old.

Two young birds were hatched this year (1911), but succumbed to the effect of a thunderstorm in July, when about ten days old. The nestling is chiefly remarkable for the length and thickness of fluffy down on the feather tracts, especially upon the head.

The exhibitor remarked that thanks to Mr. Philipps' generosity, the parents of this young bird now formed part of the Society's collection, and were amongst the rarest of the exhibits, since at the present time they were probably the only living examples of this fine species in captivity.

MR. R. I. POCKOCK, F.R.S., F.L.S., F.Z.S., Superintendent of the Gardens, exhibited two photographs (text-figs. 2 & 3) of a male specimen of Red-fronted Gazelle (*Gazella rufifrons*) which came from Kano in Northern Nigeria, and was presented to the Society in 1908 by Col. Julian Hasler. This specimen apparently represented an undescribed race which he proposed to name and to diagnose as follows:—

GAZELLA RUFIFRONS HASLERI.*

Abstract P. Z. S. No. 100, p. 47 (Oct. 31st).

Back ochre-fawn in colour with a well-defined paler area between the richer tint of the dorsal area and the infero-lateral

Text-fig. 2.



Side view of Red-fronted Gazelle, *Gazella rufifrons hasleri*.

black stripe. This stripe, as in the typical form from Senegambia, with a narrow border of fawn below. Basal inch of the tail the same tint as the back, the rest black. Only a faintly defined dark

* The complete account of this new subspecies appears here, but since the name and a preliminary diagnosis were published in the 'Abstract,' it is distinguished by being underlined.—EDITOR.

mark bordering the white of the back of the thighs. Forehead a darker and richer colour than the neck and cheeks, a few white hairs between the horns. The whole of the upper side of the nose from the preorbital glands to the nostrils snow-white like the chin. The glands themselves and the area round the eye creamy white or very pale fawn. No black on the legs or feet; the glandular tufts below the knees present as in all the examples of *G. rufifrons* that had been exhibited in the Gardens.

Text-fig. 3.

Head of Red-fronted Gazelle, *Gazella rufifrons hasleri*.

This Gazelle differed from all previously described specimens of *G. rufifrons* in the whiteness of the upper side of the nose.

MR. J. LEWIS BONHOTE, M.A., F.L.S., F.Z.S., exhibited living specimens of Rats (*Mus rattus*) which he had bred in the course of his experiments and which showed the "waltzing" character well known in a variety of the domestic mouse, but which had not hitherto been recorded in rats.

The original stock from which these rats had been bred was caught wild at Giza near Cairo (see P. Z. S. 1910, p. 664), and the experiments were being conducted to study heredity in two varieties found in a wild state, namely, *Mus rattus tectorum* with pure white underparts, and *Mus rattus alexandrinus*, in which the hairs of the underparts were entirely slate-coloured or had slate-coloured bases. The experiments were also being conducted to test the inheritance of a fawn-coloured individual which had appeared as a "sport" in the first generation from pure wild parents (P. Z. S. 1910, p. 638). With regard to the heredity of the two normal varieties the white-bellied form (*M. r. tectorum*) was found to be apparently a simple Mendelian dominant to the dark-bellied form (*M. r. alexandrinus*), the

dark-bellied ones always breeding true and the heterozygous light-bellied ones giving a proportion of pure *alexandrinus*.

This entirely bore out the suggestion put forward by Mr. Bonhote in a former paper (*loc. cit.*) that the main varieties (or sub-groups as he had called them) of *Mus rattus* were true Mendelian mutations. It would thus be understood how forms (which were at present considered as closely allied species) and which differed only in small but constant characters, were able to exist side by side under practically identical conditions without those characters becoming blended or one of them being lost, as would be bound to occur if natural selection were the *only* active force in evolution.

With regard to the heredity of the fawn—the original specimen, a male, which showed the characteristic white underparts of *M. tectorum* (its parents), was mated to an *alexandrinus* ♀, and the resulting F₁ generation, some thirty in number, were all typical white-bellied *tectorum*.

Five pairs of these were mated and gave in the F₂ generation:—

17 Tectorum, 5 Alexandrinus, 7 Fawn T., 1 Fawn A.
the expectation
being 18 „ 6 „ 6 „ 2 „

In addition, there were three individuals that died before it could be determined whether they were *alexandrinus* or *tectorum*, but they were *not* Fawn, as these could be distinguished at birth. The fawn colour, which was probably due to the absence of black, was, therefore, recessive to the normal grey colouring but might occur in either of the normal forms. Thus a rat having an absence of black and presence of the Alexandrine (slaty underparts) character was whitish fawn in colour, since the number of hairs which should contain black was much greater and in the absence of the black factor these hairs were colourless.

It might be noticed that in young Fawn Rats the eye was ruby coloured, as in the case of the Cinnamon Canary, becoming quite dark as maturity was reached.

The “waltzing” rats, of which altogether four had been produced, all appeared in the F₂ generation, but were not all from the same parents. Of the matings for the F₂ generation only one (daughter × father) produced sound young. Apart from the “waltzing” character, three individuals were born blind, and in two of these cases the eyes were undeveloped and the optic nerve absent, and in addition many of the young that were reared were so weakly that they had to be killed, and others died before being weaned.

From certain causes, therefore, which are not very clear, partly due to inbreeding, partly probably to environment, and partly possibly to their breeding at too early an age (6 months), a degenerate and defective generation was produced, and one of the results was to bring about in certain individuals a character (“waltzing”), which in a nearly allied species was shown* to have a Mendelian inheritance.

* Darbishire, ‘Biometrika,’ i. pp. 101, 165, 282 (1902), *ibid.* iii. p. 1 (1903); G. von Guaita, Ber. Naturg. Ges. Freiburg, x., xi. (1898) (1900).

PAPERS.

1. Distant Orientation in Amphibia.

By BRUCE F. CUMMINGS *.

[Received September 1, 1911 : Read October 24, 1911.]

(Text-figures 4 & 5.)

INTRODUCTION.

The observations and experiments detailed below were made in North Devonshire during the course of the last two years. The Amphibia chiefly used were two species of Newts. The British Newts have a peculiar geographical distribution in these Islands, and, living in the north of Devon, I was fortunate in being able to obtain large quantities of two species, *Molge cristata* Laur., and *Molge palmata* Schneid. It has long been the custom of field naturalists, year after year with all the precision of Gilbert White of Selborne, to note the date of the first return of Frogs and Efts to their breeding-ponds as indicative of the return of spring. It occurred to me to enquire how the Amphibia find the water again after having left it in the autumn of the preceding year. Nothing appears to be known of this subject, although the problem of these amphibian migrations is a simple one compared with that of the migrations of birds, which has attracted, and still is attracting, so much attention from the students of animal life. No one has shown how the Amphibia find the water, and it is not definitely known whether the Amphibia return to the same piece of water each spring, nor whether every animal or only a lucky small percentage finds water as the breeding season comes round, nor precisely how extensive their perambulations on land may be during the autumn months before hibernation sets in. Many larval Newts, and a few adult Newts of *Molge palmata* remain in the water hibernating at the bottom of the pond. But these are exceptional. The majority of our Amphibia do leave the water, and large numbers annually find their way back to it in the following spring. The Newt is essentially a nocturnal animal, and a visit to a newt-pond with a lantern after dark, whether in spring or autumn, is sufficient to show that night is the time when the migrations are carried on. The answer to the question how these amphibian migrations are performed must involve points of importance to amphibian psychology and, when elucidated, the subject will form an interesting chapter in their natural history. The literature is scant and vague. G. J. Romanes† thought that Frogs had a distinct idea of locality. He based this idea on the cases reported to him by some of his correspondents, where Frogs, removed a distance of 200 or 300

* Communicated by T. A. COWARD, F.Z.S.

† G. J. Romanes, 'Animal Intelligence,' p. 251.

yards from their habitual haunts, returned to them again and again. He also expressed the opinion that Frogs were able to perceive moisture from a great distance, and he quotes Warden who in "An Account of the United States," vol. ii. p. 9, says that a pond containing some Frogs having dried up, the animals "made straight for" the nearest water, though it was eight kilometres away.

COMPENSATORY HEAD-MOVEMENTS.

In all experiments with the Amphibia it is necessary to beware of error through compensatory head-movements, which, if neglected, give a false complexion to the results. No mention of them is made by Romanes' correspondents and no details of the experiments are given. It is astonishing to find how persistently Newts will return and immediately re-enter their pond, after they have been removed from it to some considerable distance. Even when placed heading directly away from the water, they turn round and walk towards the water, as if endowed with a quite uncanny knowledge of the geographical features of the neighbourhood of their breeding-pond. The explanation partly lies in the head-movements contrary to the movement of rotation, set up by the motion of the experimenter's hand as he turns the Newt round to face away from the water. The Newt mechanically responds by turning round, with the head towards the water. These movements are very pronounced in the Newt on account of its linear shape. A Newt, on a rotating disc which is being moved backwards and forwards through an angle of 180° , responds correctly if the motion is slow, *i. e.*, it turns its head regularly in the opposite direction to the backward and forward movements of the disc. If the motion of the disc be fast, it overtakes the slow head-movements of the Newt, and the Newt becomes confused and escapes from the predicament by lowering its chin so as to place it in contact with the moving disc. No response is then given. Continuous rotation in one direction produces no very marked external signs of giddiness. But in the Common Toad (*Bufo vulgaris*) these signs are marked. While the disc is moving the head is motionless. As soon as it stops, the Toad begins to crawl round in circles moving in the direction the disc had been moving. One of these animals, after rotation of one minute, in this way crawled through four circles! If a Newt be rotated through 90° in a trough with perpendicular walls two inches high, I have seen it turn in response to the rotation and climb over the side.

GEOTAXIS.

This subject must also be taken into consideration. It must be borne in mind that the ground around most ponds is sloping. Most fresh water lies at the bottom of hollows or at the foot of slopes. Newts are positively geotactic. They preferred to walk

downhill when I tested them in the spring, but in the autumn this preference changed and they went up. In work with an inclined plane, *Molge cristata* was chiefly used. The Newts were kept in water in large earthenware pans under similar conditions so far as possible. The observations were made in the early morning or at night, always in subdued light. The plane was of wood and measured 125 centimetres by 82 centimetres 5 millimetres. A line was drawn transversely across the plane, and each Newt on removal from the pan was allowed to crawl on a level surface adjoining until manœuvred with the finger into the right direction, when it was swiftly lifted on to the incline and left in a horizontal position. In this way I cut out errors arising from compensatory head-movements. An interval of ten minutes was allowed each animal before being tried again. This prevented errors arising from simple habit formation, which in the Newt is rapid.

Table I. shows the results of experiments performed in the spring when the Newts, used singly, walked downhill in 80 per cent. of the tests. Similar results were obtained by using Newts in series; twenty Newts were used. The number of positive responses was in this way reduced to 67 per cent., which perhaps is nearer the truth. Table II. was obtained in the autumn when the Newts were endeavouring to leave the water for winter quarters. The Newts were then negative and walked uphill 72 per cent. of the times. In this table the Newts were used in series, the first row being worked by twenty Palmates and the rest by twenty Crested.

TABLE I.

No. of Newt.	Incline.	Position at Start.	Down.	Up.	Neutral.	Total.
1	16°	Horizontal.	12	0	0	12
1	16°	Facing Up.	1	0	0	1
1	12°	Horizontal.	11	1	0	12
2	10°	„	10	1	1	12
2	10°	Facing Up.	2	1	0	3
3	10°	Horizontal.	12	2	1	15
3	10°	„	6	1	0	7
4	5°	„	10	1	3	14
4	5°	Facing Up.	3	0	0	3
4	5°	Horizontal.	7	3	3	13
Totals			74	10	8	92

TABLE II.

Incline.	Position.	Down.	Up.	Neutral.	Total.
8°	Horizontal.	4	19	1	24
8°	"	8	33	0	41
8°	"	13	26	4	43
Totals		25	78	5	108

The real cause of the Newts normally walking downhill may lie in the weakness of the limbs. Yet, from a few observations made on the strong-limbed Toad placed horizontally on an incline, I am induced to think that it also usually goes down, if given the choice. But, as in the case of the Newt, the cause of this behaviour of the Toad when placed *horizontally* on an incline receives a simple mechanical explanation. The kick given by the hind leg, which is higher up the incline than the other, would naturally tend at the moment of the hop to turn the animal downwards. The Toad always *hops* downhill, but it crawls and rarely *hops* up a gradient. On an incline of 12° one of my Toads would begin hopping downhill. If it was then teased on one side so as to send it up, the Toad would endeavour to continue hopping uphill, but when once facing up, the gait very quickly changed to a crawl. It may be observed that when endeavouring to hop up, the hind limbs cannot be brought up under the body from a state of extension unless they scrape the ground. After they have once scraped the ground in this way, the Toad ceases to attempt to hop, but crawls. It would appear, therefore, antecedently probable that in the spring, at the time of their greatest activity, the general tendency of the Toad also would be downhill towards water, rather than up.

One more observation is worth recording. Some Newts, when placed on a level surface or on only a slight incline, would never start off straight in any direction. They always turned, and some of their turns were very elaborate. They would meander about the centre of the board around and up and down, before setting out in any particular direction. When once started, however, they went ahead. I regard this elaborate turning merely as a complex withdrawing response. Similar behaviour has been noted in the Crayfish*.

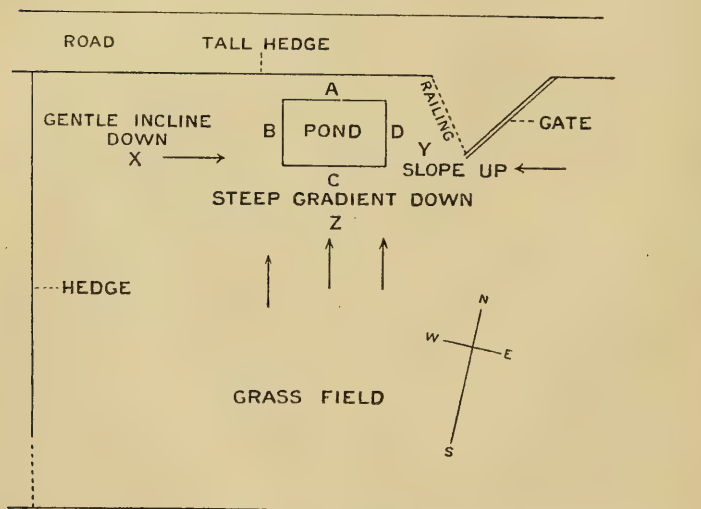
All those Newts which winter on the slopes around the pond could, by their geotactic responses, easily find their way back to the water in spring. They would simply walk downhill.

* J. Carlton Bell, "Reactions of the Crayfish," Harvard Psychological Studies, Vol. ii. 1906, p. 615.

HOMING EXPERIMENTS, 1910.

The first step was to find a pond suitable for experimental purposes, which was not easy in this neighbourhood where ponds are not common. Eventually I found a pond, which though not by any means the best possible, yet fulfilled sufficiently the required conditions. It was conveniently near home, it contained a good number of Palmate Newts, and was small enough to admit of a thorough dredging. Text-fig. 4 represents the general nature of the surroundings. The sides of the pond were bricked up, and there was a thick sediment of mud at the bottom. The three sides A, B, C, rose perpendicular from the water for a foot, while at the fourth and remaining side the water was level with the edge. The depth was 18 inches on an average, but it varied of course at different states of the weather and at different periods of the spring season. The area of the surface-water exposed was 4 sq. metres 60 sq. decimetres.

Text-fig. 4.



Plan showing pond and its surroundings used for homing experiments
Nos. 1-10.

The pool occupied a very sheltered position and was protected from all winds except those from an easterly direction. For dredging the pool I used a large prawning net on a long pole. At first I could not be sure that the pool was efficiently dredged, as it was impossible to see whether all Newts had been satisfactorily removed. Subsequently I was in several ways able to show that the pool could be thoroughly cleared, when necessary, of all Newts, if the dredging was carefully done.

In the experiments the method was to collect a number of Palmate Newts, mark them and set them loose near the pool at different distances from it. Each separate batch of Newts was given its own special mark, so that the animals when recovered could be immediately assigned to their respective batches. After several unsuccessful attempts at ringing with fine aluminium wire, I came to the conclusion that the simplest and best way of marking them was by amputating the toes of the feet in a variety of combinations.

The toe was snipped off close to the base with a pair of fine scissors. In the case of some controls, operated on and kept in an observation-pan, these animals could be easily distinguished from unmarked ones even after the lapse of two months, and this period of time for the purpose of the experiments was ample, so that I had nothing to fear from regeneration. Two days after the operation, the Newts were set loose at nightfall on the ground near the pool. They were always placed heading towards the pool, and care was taken not to influence the immediate course of the Newts through the reactions of compensatory head-movements.

Experiment 1. In this experiment twenty-one Newts were collected from a large pond 10 miles away from the experimental pond. This collection was divided into three lots of seven each, and each batch bore its distinguishing mark. On April 26th:—

Batch A was placed 15 yards from the edge of the pool on the incline X.

Batch B was placed „ „ „ „ „ on the incline Y.

Batch C was placed 10 yards up the steep slope Z.

Result. Next morning none of the marked Newts had succeeded in finding the water. On April 29th one of Batch C was recovered, and one of Batch B on the following day. On May 13th one of Batch A was taken. Thus only three were recovered.

Experiment 2. A collection of twelve Newts was made from the pond 10 miles away, marked and treated as usual. On May 8th six were placed 5 yards away at Y, and six 10 yards away at Z. These two lots were marked distinguishably one from another and from all other lots, as in all other experiments with one exception.

Result. Next day none had found the water. No signs of them on May 14th. On May 29th one, the only successful animal, was obtained. It was one of the Batch at Z.

Experiment 3. Seven more marked and imported Newts were placed at X, 5 yards from the pool, on May 26th. One was recovered on May 29th.

Recorded below are the experiments with Newts collected from the experimental pool itself and set free in its precincts after the usual treatment.

Experiment 4. Fourteen Newts were collected and on April 30th seven were placed 10 yards away at Z, and seven 5 yards away at Y.

Result. No Newts had returned by the next day, but seven were recovered on May 4th and four more on May 14th, making 11 out of the 14. In this experiment I did not take the precaution of making the two lots distinguishable when marking them, so that I could not refer the animals recovered to their respective batches.

Experiment 5. Six natives were collected and set loose on May 12th, 10 yards away at Z.

Result. None had returned on the 13th, three were recovered on the 14th. On May 29th the fourth returned, and on June 1st the fifth was taken.

Experiment 6. On May 30th six natives were placed at X, 5 yards from the pool.

Result. On June 1st five were recovered.

After this date the approach of summer weather made further work for the year prejudicial to reliable results.

HOMING EXPERIMENTS, 1911.

I took the precaution of beginning earlier in the spring this year, and the following few experiments which I was able to carry out shew that a greater proportion of imported Newts was recovered.

Experiment 7. On March 26th six natives were set loose, 12 yards away from the pool along the incline at X.

Result. Next day none had returned. Two were caught on March 29th, one on March 30th, one more on April 5th, and the fifth, and last to be recovered, on April 9th.

Experiment 8. On April 2nd six natives were set loose along the same incline but 24 yards from the pond.

Result. The next day the only successful animal was recovered.

Resuming with imported Newts, the following experiments were made :—

Experiment 9. On April 2nd six imported Newts were placed 6 yards from the pond, along the incline at X, six more 12 yards away along the same incline.

Result. The next day none had returned. On April 7th one of the 6-yards' lot was obtained and one more on the 12th. Three of the 12-yards' batch were obtained, one on April 5th, one on the 7th, and the third on the 12th.

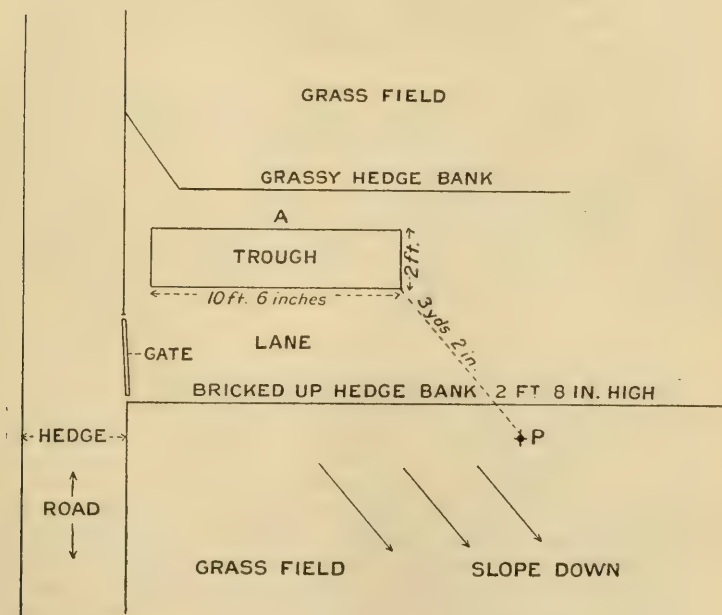
Experiment 10. On April 16th 24 imported Newts were set loose in the neighbourhood of the pond in four Batches :—

- | | | | | | | | | | | |
|----|---|------|--------|----|-------|-------|-----|---------|----------|----|
| A. | 6 | were | placed | 5 | yards | along | the | incline | X. | |
| B. | 6 | " | " | 12 | " | " | " | " | X. | |
| C. | 6 | " | " | 24 | " | " | " | " | X. | |
| D. | 6 | " | " | 40 | yards | up | the | steep | gradient | Z. |

Result. On April 18th one of Batch B was caught and two of Batch A. On April 22nd one more of Batch A was obtained.

Experiment 11. In this experiment four full-grown Palmate Newts were taken from a horse-trough about one foot deep near the experimental pond. The trough was only 2 inches above ground level. Text-fig. 5 shows the nature of the ground around this trough and the point (P) at which these four marked Newts were set loose, together with four young Frogs, also caught in the trough, the eight specimens being the whole of the amphibian live-stock which the trough contained. The Frogs were young—not more than 10 or 11 months old and hatched the previous spring, judging from their size. These eight specimens were set loose on April 16th.

Text-fig. 5.



Plan showing the horse-trough and its surroundings used for homing experiment No. 11.

The spot where they were set loose was deliberately chosen as the most unfavourable one from which the Newts might be expected to be able to return. They were set heading down the slope away from the trough.

Result. The trough remained empty until May 16th, when one of the four Newts was recovered.

HUMIDITY EXPERIMENTS.

In order directly to test Newts for a supposed faculty for perception of humidity in the atmosphere, I planned apparatus to work with electric fans driving two air currents which were to be kept at an even temperature and velocity. One current was to be thoroughly saturated by passage over a series of porous plates containing water, and the other to be kept dry. The Newt to be tested was to walk down an inclined runway, and to be exposed on one side to the wet current and on the other to the dry. At the bottom of the runway it was free to move in the direction of either current. Fortunately for me, before carrying out this elaborate apparatus in detail, I took the precaution of making a few of what I considered would prove only preliminary trials with a simpler arrangement in which the temperature factor was not eliminated. I quickly formed the opinion either that Newts were unable to detect moisture at a distance and slight variations in temperature, or that my method of experimenting was unsatisfactory.

Although the existence of this faculty—which Romanes favoured—seems improbable in the face of the facts recorded in the two previous sections, an ingenious experimenter might perhaps obtain more encouraging results. I think, though, such a perceptive power in Newts would prove to be of too slight a nature to be easily demonstrated by a laboratory experiment, and especially by one such as mine, where a turn right or left at the end of a runway, after a comparatively short exposure to the conditions, was to decide each test.

DISCUSSION.

The evidence presented, fragmentary as it is, lends support to the hypothesis that Newts and presumably other Amphibia possess a homing faculty. Table III. is interesting, particularly that part dealing with the imported Newts, as one would have been led to expect more of these to return if only by chance; for they were set loose at very short distances from the pond (with one or two exceptions). But then the small size of the pond must be remembered, particularly in comparing with the account in Romanes' 'Animal Intelligence' where no mention of the size of the pond concerned is given. It will be seen that more imported Newts got back in 1911 than in 1910. This may be explained by the fact that experiments in 1911 were begun earlier than in 1910, when the Newts might have already done some breeding before being caught. Their desire to find water would then be proportionately less. This qualification does not apply to the natives, as the same natives were used several times over and their breeding was therefore prevented up to May in both years. Furthermore, in the experiments of 1911, the Newts, both imported and native, were set loose, with one exception, along the incline X. This incline was undoubtedly the most

TABLE III.

(a) *Imported Newts.*

Exp. 1910.	Number set loose.	Position.	Distance in yards from the pool.	Number recovered.
1 ...	7	X	15	2
1 ...	7	Y	15	0
1 ...	7	Z	10	1
2 ...	6	Y	5	0
2 ...	6	Z	10	1
3 ...	7	X	6	1
1911.				
9 ...	6	X	6	2
9 ...	6	X	12	3
10 ...	6	X	6	3
10 ...	6	X	12	1
10 ...	6	X	24	0
10 ...	6	Z	40	0
76				14

(b) *Native Newts.*

Exp. 1910.	Number set loose.	Position.	Distance in yards from the pool.	Number recovered.
4 ...	7	Z	10	} 11
4 ...	7	Y	5	
5 ...	6	Z	10	
6 ...	6	X	5	
1911.				
7 ...	6	X	6	5
8 ...	6	X	24	1
38				27

favourable position for the Newts from which to find the pool. It was a gentle incline down, and they would naturally walk down it. On the other hand, if they turned to the right, they were confronted with the steep gradient Z which in all probability they would not negotiate. The hedge on the left was the only thing which may have lured them away from the right path. In 1910 the number of natives in the pool was twenty-two. In 1911 this supply had fallen to twelve, and two of these still bore marks, sufficiently clear for me to be able to identify them as belonging to batches of native Newts set free the previous year. These two at all events must have wintered near the pool and returned to it in the spring. The decrease in the supply of natives in the spring of 1911 may be explained when I say that seven of the original twenty-two were accidentally killed before they could be returned to the pond at the close of

the 1910 work. It is probable from this that the number in any one pond remains fairly constant. It will be noticed that of the native animals set loose in Experiment 11 only one got back. These were set loose, however, as will be seen in text-fig. 5, in the worst possible position I could find from which the Newts—even natives—might be expected to return. The slope led away down the field from the pond and the field was separated from the trough by a drop of several feet and a hard road three yards across.

A decisive result brought out by these homing experiments is that Newts certainly have no very definite faculty or instinct for detecting water even from a short distance (see Table III.); and in this connection attention may be drawn to the length of time usually taken by the native Newts in finding water from short distances. They perhaps rely on a combination of small clues, for, in addition to the downhill tendency and a small homing faculty, a supposed sensitiveness to atmospheric moisture at a distance and to slight variations in temperature, I can suggest as auxiliary factors (but can adduce no evidence for or against):—a sense of smell for detecting stagnant water and a sense of hearing for discovering other Amphibia already in the water, or, in those Amphibia which live in streams, for discovering running water.

Either all or a few of these may provide the animals with clues, small though some of them would be. In this paper a combination of the downhill tendency and a homing faculty is considered as the chief factor.

I was very anxious to make more experiments with natives, but the stock became exhausted and this brought my work to a premature close.

CONCLUSION.

This paper does not pretend to present a conclusive case on the subject of amphibian migration. But the results of the experiments are suggestive, and the opinions I have formed from them are:—

1. That Newts are helped to find water in which to breed by their marked tendency to walk downhill. Those animals hibernating on the slopes around their pond would simply have to walk downhill. A good many young Newts I have found hibernating in this way, close to the water of their native pond. It may be a wise precaution, because young Newts of the year would not have any knowledge of locality.

2. That there is a small homing faculty in Newts, which probably consists in a topographical knowledge of the locality where the breeding pond is situated.

3. That they are able to “home” from only short distances and that, therefore, both their topographical knowledge and their terrestrial wanderings in autumn and winter must be rather circumscribed.

4. That, speaking generally, the same Newts return to the same pond each year.

5. That those Newts which wander away from the precincts of

the pool, become "lost" and only regain the water by chance or, for a season, may even fail altogether to reach water and to propagate their kind. Field naturalists are well acquainted with the Newt's capacities for travelling.

6. That further experiments on a more extensive scale ought to settle this matter; suitable ponds, however, are difficult to find, particularly in this part of the country.

I hope those living in more favoured localities will be induced to carry these preliminaries to more decisive results.

In conclusion, I should like to thank Dr. R. M. Yerkes, of Harvard University, for the encouragement he has given me in this undertaking, and my sister for her services in obtaining specimens and in dredging.

2. Some Remarks on the Habits of British Frogs and Toads, with reference to Mr. Cummings's recent communication on Distant Orientation in Amphibia. By G. A. BOULENGER, F.R.S., F.Z.S.,

[Received November 6, 1911; Read November 21, 1911.]

In the course of the discussion which followed Mr. Cummings's communication at the Meeting on October 24, I made some remarks on the habits of Batrachians, which the Secretary has asked me to embody in a short paper for the information of those who might feel inclined to carry on further observations in this country on the interesting subject with which Mr. Cummings has dealt.

There is great diversity among Tailless Batrachians in the possession, lack, or degree of instinctive foresight in selecting places for the deposition of their eggs. Leaving out the thoroughly aquatic Edible Frog (*Rana esculenta*), which has only doubtful claims to be regarded as British, two of our species, the Common Frog (*Rana temporaria*) and the Natterjack Toad (*Bufo calamita*), belong to the category of the least gifted in this respect, whilst the third, the Common Toad (*Bufo vulgaris*), behaves differently, and is besides possessed of an instinct for orientation which appears to be highly developed. The fact that, after the perfect condition is attained, Tailless Batrachians, unlike the Tailed, do not regenerate lost parts, would render the Common Toad further suitable for experiments on migrations, after the amputation of a finger or toe, as a distinctive mark. The Natterjack is, with us, a very local species, but the Common Toad and the Common Frog are ubiquitous and, as young or outside the breeding-season, are often found far from water, to which they have, of course, to resort for oviposition. How the three species behave in connection with this function I will tell briefly from my own observations.

The COMMON FROG exercises little discrimination in the choice

of water in which to deposit its eggs, provided it be not brackish, often spawning in temporary winter pools which are sure to dry up before the time at which the larvæ have completed their metamorphosis, or on the edge of a pond where, the level of the water falling after dry weather, the egg-clumps remain stranded. No doubt the frogs are attracted to the shallow, slanting borders in preference to the deeper parts with abrupt banks by the comparative warmth of the water under the sun-rays of late winter or early spring, with the unfortunate result which may be witnessed almost year after year in some places, when, following a spell of dry weather, the borders of ponds are covered with the stranded jelly-like masses of frog-spawn drying away in the sun before the liberation of the larvæ. On my country rambles in the end of March or beginning of April, I have often rescued the progeny of many frogs by removing such doomed egg-masses from these fatal beaches to deeper water close by, which the mother would have chosen had she been gifted with the instinct possessed by the Common Toad.

The migrations of the Common Frog towards the water must take place, to a great extent, in the autumn, as many, perhaps the majority of individuals, hibernate buried deep in the mud at the bottom of ponds, sluggish but not dormant as in some higher animals. Some years ago, just before Christmas, after a period of severe frost, which had lasted more than a week, I was walking on the ice of a small and shallow pond in Belgium, when my attention was drawn to a bright red creature, first taken for a gold-fish, moving under the ice, which very nearly extended to the bottom of the pond; this was a Common Frog, and on looking closer, I discovered hundreds of others, less conspicuous owing to their yellowish, brown, or olive colour. Some were very handsome specimens, which I wished to secure. A pick-axe was fetched from a neighbouring farm and a hole made in the ice, through which I could introduce my arm and reach the bottom; but the frogs were so active that they swam away and not one could be caught. I decided to return to the pond after the thaw, which I did, but no more frogs were to be seen; they had evidently retired to their hibernating-quarters in the mud and in holes under water. The reason why they came out when the pond was frozen nearly to the bottom, must be attributed to the reduced oxygen in the water, which made the frogs, breathing as they do under such conditions chiefly by the skin, feel uncomfortable and desire to escape.

The Common Frog is the earliest breeder among European Batrachians, spawning taking place in the South of England from between the end of January and the end of March, the date depending almost entirely on the temperature and therefore varying considerably from year to year. Should the winter be a mild one, the breeding may be over by the middle of February; recurrence of cold weather after the frogs have begun spawning may cause them to return to their winter-quarters, with the

result that the breeding-season is broken up into two or three periods within a couple of months. When the first appearance of mild weather is much retarded, the spawning takes place for all individuals within a very few days, with an *ensemble* which is not customary for the species in our uncertain climate.

The NATTERJACK TOAD does not undertake lengthy migrations for the purpose of depositing its eggs. It usually lives in colonies in sandy localities, such as dunes on the sea-coast, sand-quarries, heath-land, etc., which must be in close proximity to at least some sort of shallow pool, even of an intermittent kind. This toad shows not the slightest discrimination in the choice of water, and will not move any distance in search of better conditions if only it can find close by a little water in side ditches or even in cart-ruts of a road, whilst an excellent pond may be available a hundred yards off. The development of the eggs and larvæ, it is true, is much more rapid than that of earlier breeders like the Common Frog and the Common Toad, but nevertheless, in some places, a great many broods are destroyed through want of foresight on the part of the mother. Should, however, the pools or ponds in which the Natterjack is accustomed to breed, and around which it has settled, disappear for good, by the agency of man or otherwise, the whole colony will move off after a time to a more suitable locality. This I have observed in sand-quarries in Belgium and France, some of which are provided with stagnant water whilst others are not; those which have no water or from which the water has disappeared for a year or two, are without Natterjacks at all times of the year, thus showing that this gregarious Batrachian only settles down in such places as will afford a site for spawning within a few yards, whilst half a mile's journey is nothing to a Common Toad. It may also be mentioned that the Natterjack, in common with the Palmated Newt, has no objection to brackish water and is therefore often found in great abundance in close proximity to the sea. The greatest number I have ever seen was on the little ile de Bast, opposite Roscoff, on which, for the reason that the pools are brackish, neither frogs nor the common toad exist.

The Natterjack has no such restricted breeding-season as our other Tailless Batrachians. The females do not go to the water until ready to spawn, and the time at which the ova descend into the oviducts varies according to individuals, from between the middle of April to the beginning of July, sometimes even later.

The COMMON TOAD, on the other hand, is remarkable for the fixity in the time at which it seeks the water for the purpose of reproduction and for the shortness of the period within which all the females get rid of their eggs. Exceptions of later breeders, which have been observed, are so rare they may well be said to confirm the rule. The same may be said of isolated pairs occasionally found in places to which toads are not in the habit of resorting to breed.

The breeding-season in the South of England, the North of

France, and Belgium, falls within the last days of March and the first days of April, and, with the exception of severe frosty weather, which rarely occurs at that season, irrespective of the temperature. Then certain ponds or deep flooded quarries will be found alive with hundreds or thousands of toads which have congregated from the neighbourhood, often from a radius of half a mile or more. Thither all the toads have travelled with remarkable directness, passing other ponds or ditches of which they might avail themselves were it not for the instinct which leads them to select a place offering all guarantees for the successful rearing of their progeny. If a male meets a female *en route*, he vigorously clasps her under the axils and accomplishes the rest of the journey on her back. Much of the travelling takes place at night, but individuals are also met with in the daytime, hopping along towards the meeting-place. If a high road should run not far from the pond which is the rendezvous, numbers of crushed corpses of toads, run over by motor-cars or other vehicles, will be found for a distance of perhaps two or three hundred yards, the crushed toads being more and more numerous as the road nears the pond.

If pairing toads are taken from the place selected by them for spawning, and removed to a neighbouring garden with a small artificial pond in which, we should think, they might comfortably conclude their breeding-operations, they will often leave and start off in the direction whence they were brought. It does not matter to them whether this be up or down hill.

Some years ago I made an experiment on the instinct of orientation in this toad. I took a number of pairing individuals out of a pond frequented by the species, which was only a short distance from another in which frogs spawn but to which toads never resort. I turned them loose on a monticule midway between the two ponds, from which neither could be seen, and watched their movements. All, after a little hesitation or after a few hops in the opposite direction, took the right orientation and made their way straight towards the pond whence they had been taken. I experimented on single individuals, on pairs, and on groups of individuals, with the same result. In this case, it was evident that the toads were not influenced by hygroscopic sensations, since there was water in both directions. Whether the sounds uttered by their fellows in the pond were a guidance to them, seems to me doubtful, considering the very feeble voice of the Common Toad, the males of which, as is well known, are devoid of vocal sacs; if so, it would denote a very acute sense of hearing in toads. I am, however, convinced, from other observations, that even at a greater distance, from which no such sounds could be heard, the toads would have taken the right direction.

I strongly recommend the Common Toad as the most suitable Batrachian on which to institute series of experiments on distant orientation.

3. Game Sanctuaries and Game Protection in India.

By E. P. STEBBING, F.L.S., F.Z.S., F.R.G.S.

[Received June 6, 1911 : Read October 24, 1911.]

I. INTRODUCTORY REMARKS.

Could some of the great sportsmen who lived and revelled in the land half a century ago revisit the scenes of their former exploits, how, it may be wondered, would their favourite shooting-grounds strike them at the present day?

We have all read our Forsyth's 'Highlands of Central India,' Sterndale's 'Seonee or Camp Life in the Satpuras,' Saunderson's 'Thirteen Years' Sport in India,' Simson's 'Sport in Eastern Bengal,' Pollok's 'Sport in British Burma,' Pollok and Thom's 'Wild Sports of Burma and Assam,' Pollok's 'Sporting Days in Southern India,' Kinloch's 'Large Game Shooting in Thibet, the Himalayas and Central India,' Col. Fife-Cookson's 'Tiger Shooting in the Dun and Alwar,' Baker's 'Wild Beasts and their Ways,' Eardley-Wilmot's 'Forest Life and Sport in India,' etc. What lesson does a perusal of these fascinating volumes teach us—inevitably tell us? That the Game of India is on the decrease and on a very rapid decrease, and that the good old days of yore are gone, never to return.

That the modern rifle has to some extent been responsible for the present state of affairs is beyond cavil—its accuracy and also the cheapness with which the more roughly made forms can be purchased. The native shikari has now to some extent replaced the old blunderbuss of his father's days by a breech-loader, and when possessed of such kills an infinitely larger head of game in the year as a consequence. The weapon itself costs Rupees 45 only, but it is doubtless the price of cartridges which mercifully prevents the breech-loader from coming into as general use amongst this class of men as would otherwise be the case.

But the startling decrease which the head of game existing in India has undergone during the last two or three decades cannot be attributed only to the improved accuracy of the weapons with which the modern-day sportsman is armed. The opening out of the country and the consequent restriction of the animals is largely responsible. For instance, Bengal and Assam, *e. g.* the Western Duars, no longer contain sufficiently extensive jungles to harbour rhinoceros and buffalo. The great increase in the number of sportsmen who visit the jungles annually on sport intent, an increase brought about chiefly by the greatly improved communications owing to railway and road development, has also been a great factor in the case; and, finally, the infinitely greater number of competent native shikaris in existence; I write "competent" in the sense merely to express their power to *kill* game. The vast majority of these men are poachers pure and simple, as were their fathers and fathers

fathers before them. Formerly, however, owing to their antiquated low-power weapons, the damage they were capable of doing was of a negligible quantity: nowadays it is far otherwise, and the methods to be put in force to deal with them form one of the most difficult problems those responsible for the upkeep of the game in the forests, and country generally, have to solve.

The plea ever placed in the forefront by such men is that the guns are required to protect their crops, and this plausible excuse has been accepted by Local Government after Local Government; and we can quite see the difficulties that have faced the latter, and still do so, in a settlement of the question. It cannot, however, be said to have been ever satisfactorily or fairly faced, and this inaction on the part of the central authority has checkmated the efforts of many a Collector and Forest Officer in his attempts to keep down the number of (poaching) guns in a district. A sympathetic Government has always been too eager to listen to the tales of destruction to crops, and the District Officer, without local knowledge, prefers to err on the side of liberality, and so readily grants licenses to applicants.

We all know the way these license gun-holders go to work. A machan (platform) is built on a known deer-run on the edge of the forest and just without its boundary, if not inside, with the connivance of the Forest Guard. The shikari occupies his post in the late afternoon, and by sunrise next day several bucks and does may be lying round the machan; the skins, horns, should there be any of the latter, and the flesh are taken off to the bazaar, where a ready sale is found for them throughout the country. The meat is sold locally, the skins and horns being bought by middlemen for export. It is a common thing to see on the platform at wayside stations near forest-areas piles of skins and horns booked, and openly booked, in defiance of all rules and regulations, to some large centre.

I would not be understood to say that it is the native shikari alone who acts in this way. It is an open secret that the native soldier of shikar-loving propensities, as also his British brother, will act in an exactly similar manner on occasion. Once, however, this matter is properly faced, the latter class of offenders can easily be coped with. For the non-military native offender a license to protect his crops should be given only after careful personal enquiry on the ground by the District Officer. Also the sale of venison in the open market should be made a criminal offence.

The whole crux of the position is, of course, the necessity for regulating the number of animals shot, so as to prevent deterioration or extermination of the game. On the whole, the European is more destructive than the native to the animals which are greatest in need of protection. Rules and the proper control and management of shooting-grounds can control the European. The native is, however, not so easily dealt with. In order therefore to arrest the slaughter which takes place ostensibly to

protect crops, some special measures are necessary. Wherever it can be proved that game is no longer destructive, the licenses should be cancelled and the weapons called in. In other cases where destruction is still being done the guns must be retained. Since, however, these weapons are given merely for the protection of the crops, they should be restricted to that purpose and be rendered unfit for any other. This can be easily done by cutting down the gun-barrel to 18 inches or 2 feet.

A further point of importance in connection with the protection of game is to be found in the sale of ammunition. It is a question for consideration whether this should not come into the hands of Government and be directly regulated by it. This question scarcely comes under the head of Game Sanctuaries, but it is of very considerable importance in the interests of Game Preservation.

The apathy which the proper protection of the Game of the country has met with in the past at the hands of Government is almost incredible. In many parts of the country there are forests in blocks of very considerable area. Rules under the Forest Act have been in force in these forests for years, a sixth of British India being under the Act and Rules. It would have been sufficient merely to have enforced these rules in the spirit as also in the letter, and adequate protection would have been afforded to species which are now, owing to this apathy and neglect, within a measurable space of deterioration, if not of total extinction.

Lord Curzon, so long ago as December 1901, when replying to the Burma Game Preservation Association at Rangoon, said he was in "close sympathy" with the aims of that body.

That he recognised the importance of the subject is shown by his opening remarks, in which he said:—"Among the many memorials which the enterprising inhabitants of Lower Burma have showered upon me, and to all of which it has not been possible for me to give a verbal reply, I have selected yours as one of those to which I should." He then observed that the great importance of the question of Game Preservation in India is one that, in his judgment, appealed not only to the sportsman but also to the naturalist and the friend of animal life.

Further on he stated that facts pointed entirely in the direction of the "progressive diminution of wild life in India," and gave examples in support of this belief. He then mentioned some of the "artificial and preventable" causes of this diminution, and also of those which are "natural and inevitable." He admitted that hitherto the attempts made by Government to deal with the question by legislation or by rules or notifications based on statutes had been somewhat "fitful and lacking in method," and, after mentioning some of these attempts, he said:—"The general effect of these restrictions has been in the right direction, but I doubt if they have been sufficiently co-ordinated, or if they have gone far enough, and one of my last acts in Simla, before I had

received or read your memorial, was to invite a re-examination of the subject, with the view of deciding whether we might not proceed somewhat further than we have already done."

His idea was "to frame some kind of legislation of a permissive and elastic nature, the provisions of which should be applied to the various provinces of India, in so far only as they were adapted to local conditions." Unfortunately, however, he did not deal with one of the most difficult sides of the question, viz., the co-operation of Native States; he merely observed that this question is "somewhat complicated," and expressed his belief that "The Government would meet with the willing co-operation of the Chiefs."

There does not appear to be at the present moment, notwithstanding the Viceroy's action, so far back as 1901, any Act or Regulation issued by the Government of India, defining the principles governing the protection of game, and the means by which such protection should be effected.

Of late, however, matters for the protection of game have to some extent considerably improved, and Local Governments throughout the country have revised their Game Rules, and in some cases have ordered the formation of Game Sanctuaries in addition to limiting the number of head of game to be shot in a district or block of forest to a definite number per year. Further, in certain provinces sportsmen are only allowed to kill individually a certain head of each different species of animal, thus eliminating the worst feature of the old-time sportsmen—the butcher, whose boast was not the size of the trophies he obtained so much as the *number* of animals he had killed. For the departures thus made throughout the country I think a due meed of credit should be accorded to the Nilgiri Game Association. Inaugurated about 1885, this Association has now for years not only protected the game of the Plateau which the sportsmen and the Todas between them were surely exterminating, but has enabled an increase to be maintained and recorded. The last annual reports of the Association point to a satisfactory increase in the head of Saddlebacks (*Hemitragus hylocrius*) and the Sambhar (*Cervus unicolor*). For some years past the number of such to be shot by each sportsman has been regulated under the authority of the Association, directly supported by Government. The departure thus initiated in the distant Southern Plateau was followed in the far North when the game of Kashmir was threatened with extinction owing to the annually large recurring influx of sportsmen who visited the Fair Vale. Game Protection in Kashmir now forms a separate Department of the State, as, I think, it should in British India, and one which has fully achieved under its able head the objects anticipated from its inauguration. The enlightened ruler of Chamba State also took up the question, and prohibited all shooting except on passes issued on his own authority.

Whilst such laudable commencements were thus made to

preserve the game of areas which, owing to their peculiarly favourable climatic conditions for the European sportsman, were threatened with extinction, the Local Governments in India were very apathetic in the matter. Game Rules were in existence for the Forest Reserves of the country, but they related chiefly to a close season, the latter in some cases only applicable to the females, and the same was the case for the open country, where the rules usually related to birds only. These regulations were, however, openly broken, and the penalties in existence were practically rarely put into force, except by some exceptionally energetic officer; and even then an appeal was usually upheld and the orders passed reversed.

At length, however, the apathy that hung over this question gave place to some show of interest, which was followed by activity on the part of the Government of India, on whom it had slowly dawned that there was perhaps some reason for the outcry, increasing in intensity each year, that the game of the country was doomed and that but a few years separated it from extinction. Local Administrations were addressed on the subject of the Rules and Regulations in force in their Presidencies and Provinces under the Forest and other Acts, and as to the steps necessary to be taken to prevent the extinction of the several heads of game, excluding carnivora. This led to many separate enquiries being undertaken throughout the country, to a prolific correspondence in the Press, of which desultory rumblings are still heard, and to many improvements being initiated in the Shooting and Game Rules throughout India. I am aware that I am laying myself open to serious attack in thus stating the case, but it is maintained that any and every rule that is made with the idea of *protecting* the game of a country is a step in the right direction, and therefore advantageous both to the sportsman and the game itself, however hard it may seem to fall on a particular body of individuals or a particular individual. This point will be referred to at some length later on, but I would like to appeal here to the public spirit and fairness of all true sportsmen to aid to the best of their abilities the present endeavours of the Government of India in the direction of arresting the destruction of Wild Animals. I feel sure that the Government will approach this matter in a much firmer spirit if they feel that they have behind them the good wishes of a solid mass of sportsmen throughout the country.

What is required is to fix the close seasons definitely, and the Government of India have now, as we shall see, proposed to legislate to give power to fix a close season for different kinds of game.

In a series of articles published in the 'Indian Field' between the dates 6th June, 1907, and August 1907, a writer thus approached this question:—

"We presume that the Imperial Government, as proprietor of all the game in the country, is the most important party concerned

in its preservation, and that in effecting this object it has every right not only to safeguard this valuable asset, but also to obtain a reasonable profit therefrom. Less than half a century ago this principle was acted upon when forest lands were taken possession of, and now the villager has to pay for every bundle of grass and bamboo that he obtains from Government forests for building his humble abode." This latter, by the way, is not a true representation of the actual facts of the case, for many forests are burdened with "rights," under which large amounts of forest products are annually given away free to villagers by the Government.

"The agricultural community is certainly the next important body whose interests will be affected. In European countries, in England for example, the population have a firm conviction that the right of killing game belongs to them, contrary to the practice of centuries. In India, no such difficulties surround the game-protection question. The occupiers of the soil have no conviction whatever that they possess the right of property in the game animals and birds that abound in their fields and jungles. They are concerned only about the protection of their crops from the raids of these animals. If this right of protection is recognised, and the Government which assumes ownership of all game acknowledges its responsibility in this respect, it can be confidently stated that no apprehension need be felt regarding the attitude of the Indian rural population towards the proposed law. Legislation for the protection of game in this country will not create any feeling comparable to that which still exists in the minds of the people regarding the action taken by Government when forest lands were resumed fifty years ago." The analogy, it may be pointed out, scarcely holds, since the forests of the country are protected solely in the interests of the people themselves and posterity, whilst the protection of game is undertaken in the interests of the sportsman and in that of science.

"The third class which will be affected by this law is sportsmen, European and Indian. In the former category should be placed, first, the official who is backed by Government authority and his favoured friends who are given all the facilities which his position allows; next, the solitary hunter with his small camp and all the Game Regulations of the Province to keep him in the right path. The subdivisions in this class are numerous, and include the unemployed colonel putting in his time, the subaltern out on ten days' casual leave, the humble clerk who can occasionally get away from his office for a week, and the British soldier let loose in parties for fixed periods.

"Next comes the Indian shikari, who is also numerously subdivided. There is the rich land-owner, possessed of unlimited sporting appliances and his host of followers; the professional game-killer who lives by his licensed gun; the small landholder who does not know how to use a firearm, but whose dignity is enhanced by the possession of weapons,—freely lent to his

underlings for supplying his kitchen with fresh meat; and, finally, the half-starved villager of the meaner castes, who is given a gun for use at night in the fields, but which weapon is regularly and illegally used for the destruction of game animals of every prohibited class. In this inventory, the Gurkha soldier does not find a place, for he belongs to a class which he amply fills by himself with his small but very important personality. He deserves separate notice. From the banks of the Sarda on the frontier of Nepal, to the banks of the Indus, the battalions of these gallant little men are scattered in cantonments all along the outer spurs of the Himalayan range. In seven or eight of these locations there are at least fourteen thousand of these disciplined warriors, who, in the absence of opportunities for spilling human blood legitimately, are given a free hand for slaughtering wild animals, along five hundred miles of the best hunting grounds in Upper India."

I propose, then, to consider first the question of the formation of Game Sanctuaries, defining a Game Sanctuary and the different ways of forming them, and detailing what has been done under this head in the several Presidencies and Provinces of the country and what in my opinion it would seem still remains to be done.

I shall then give an abstract of portions of the proposed new Indian Game Act, making some suggestions for specifying more distinctly than the Act does at present the various classes of game, and suggesting that the game animals and birds, as also useful insectivorous birds, shall be severally mentioned in the Act by name. I shall then indicate some specific suggestions for the formation of close seasons and for the closing to shooting of species which have been decimated by drought, anthrax, etc., and for the definite regulation from year to year of the number of head of particular species to be shot in given areas; concluding, finally, with some remarks on the subject of the proportion of the head of game of a district to be shot respectively by the district officials and the outside sportsman.

II. THE GAME SANCTUARY.

The idea of the Game Sanctuary was a natural outcome of the indiscriminate slaughter to which wild animals have at all times and in all countries been subjected by man. So long as it was man imperfectly armed against the animal with his natural sagacity or fierceness to protect him, conditions were equal, or in favour of the animal, and there was no reason for intervention. From the day, however, of the introduction of the breech-loader and the repeater and a whole host of perfectly built weapons of every kind, enabling man to kill with comparative ease and certainty, the odds were against the animal and the question of affording some degree of protection to the game of a country became of paramount importance; and, curiously enough, the

question became most vital in the more uncivilized, uninhabited, and wilder portions of the globe. Such shooting grounds were open to one and all, just as for centuries the shooting in India had been open, with the result that the modern rifle soon threatened the extinction of all game. That modern conditions have rendered this quite feasible the two well-known and oft-quoted instances afforded by the practically extinct American bison and the extinct quagga of South Africa sufficiently illustrate.

In India we have come within measurable distance of exterminating the rhinoceros (*Rhinoceros unicornis*), which, together with the elephant and the gaur or Indian bison (*Bos gaurus*), would without protection probably soon disappear from the jungles which have known them for so long.

It may be mentioned here, in passing, that Indian ruminants, such as the gaur, sambhar, etc., and the elephant, have always had to contend against a sickness resembling anthrax, and also against drought, which at times have decimated their numbers over large tracts of country.

With a view to affording a certain protection to animals of this kind and of giving a rest to species which have been heavily thinned in a district by indiscriminate shooting in the past or by anthrax, drought, etc., the idea of the Game Sanctuary was introduced into India (and in other parts of the world) and has been accepted in many parts of the country. The sanctuary consists of a block of country, either of forest or grass-land, etc., depending upon the nature of the animal to which sanctuary is required to be given; the area has rough boundaries such as roads, fire lines, nullahs, etc., assigned to it, and no shooting of any kind is allowed in it if it is a sanctuary pure and simple; or the shooting of carnivora may be permitted, or of these latter and of everything else save certain specified animals.

Sanctuaries may be formed in two ways:—

I. *The area is automatically closed and re-opened for certain definite periods of years.*

II. *The area is closed until the head of game has become satisfactory, and the shooting on the area is then regulated, no further closing taking place, save for exceptional circumstances.*

I. *The Sanctuary is automatically closed and re-opened for a definite period of years.*—The Sanctuary is notified for a period of years: this period would naturally be variable, but it is of importance, I think, that it should not be placed at too great a length, or the animals in the sanctuary, so long immune from danger, would on the re-opening of the area be so unused to the sportsman that they would be shot down in a very short space of time. Probably the period during which a block of forest is closed to all shooting should never exceed, at the most, three years. That good sportsman Sir John Hewett considers that a period of five years for a sanctuary is too long. He thinks that the ground of the sanctuary should be changed every two or three years, probably the former, and

that the animals would soon learn where the sanctuary was. He also agrees that before opening a sanctuary to sportsmen the area should be *beaten* through so as to distribute and disperse the game, and not have them collected together Noah's-ark-fashion on a large scale for the first permit-holder who enters to shoot down with ease.

Whilst, however, this system of opening and closing areas to shooting is best adapted to some localities and to certain classes of game, it is quite inadequate for the satisfactory protection of others. In many parts of India I would favour the second suggestion as being by far the most satisfactory in the long run and in some cases essential.

II. *The area is closed until the head of game has become satisfactory, and the shooting on the area is then definitely regulated, no further periods of closure being enforced save for exceptional circumstances.*

The length of time a Sanctuary should be in existence is of very considerable importance, and to a certain extent is intimately dependent upon a knowledge of the habits of the animals for which the sanctuary is formed. The period of closure to be effective must depend :—

(1) On the condition of the head of game of the area when the sanctuary is first formed.

(2) *On the nature of the animal*, e. g., the rhinoceros, with a period of gestation of two years and a period of fifteen years before it reaches maturity, would require practically permanent closure of its haunts to produce any appreciable result, as has, in effect, been carried out in Goalpara in Assam.

The procedure followed should usually be determined by the condition of the head of game on an area. There would be no question of fixing a definite period for the sanctuary in the first instance. When the requisite effect on the game had resulted from its formation, careful and efficient rules and management should be sufficient to keep up the head of game, and it would not be necessary to continue the rigid exclusion of sportsmen. It would be sufficient to limit *the number of head of each species* to be shot *each year*, as is done in many parts of the Central Provinces. When the limit had been reached the shooting of that species in that locality would cease for the year.

Once a sufficient head of game has been established in a locality, it is questionable whether regulated shooting each year would not have a better effect than the alternative proposal of closure for a term followed by a period of unchecked shooting. It would certainly minimise the chance of the animals becoming too tame.

The size of a Sanctuary must, of course, entirely depend on local conditions and on the nature of the animals to be protected. Such animals as the rhinoceros or gaur, which are of an extremely shy disposition and are given to roaming considerable distances, would require an area of considerable dimensions, whereas chital

(*Cervus axis*) and hog-deer (*Cervus porcinus*) would require a comparatively small one.

Pheasants, again, would not require large areas, and the same applies to the hill sheep and goats—a nullah or certain nullahs being prescribed as closed to shooting, as, in fact, is done in Kashmir.

Game Sanctuaries may be of several kinds :—

1. Entirely closed to all shooting.
2. Closed to beating only.
3. Closed to the shooting of certain species of game.
4. Closed to shooting of all game, save noxious ones, such as carnivora, pig, etc.

The question of enforcing the sanctuary law against shooting is one of some difficulty. In Reserved Forests it is comparatively easy, since all shooting without special passes in such areas is forbidden and the granting of these would be stopped for sanctuaries. Outside, however, the matter is by no means so simple, and the people of the country, particularly the shooting element, will require a careful education if they are to understand and respect the sanctuary, should it be formed in Government Waste Land. It will be necessary to fully explain the uses of sanctuaries, and the reason for closing the areas as soon as attempts have been made to form them.

At present anyone may enter on land, which is not reserved forest, and shoot. To alter this would at once curtail what is a prescriptive right, and this is the main obstacle to the introduction of a Game Law. Rich and poor alike enjoy this privilege, and although the occupier may in time come to learn that shooting rents can add to his income, or reserve his waste land for his own shooting and close it to the general public, as is done in many cases in the Dun below the Mussoorie Hills, it will be difficult to introduce restrictions on areas in which shooting is practically a right in all but name.

It is, we fear, hardly to be expected that the question of the formation of sanctuaries and their closing will be received without opposition throughout the country even amongst the Europeans, but I am of opinion that the matter is one of such great importance that the outcry of the few interested people opposed from personal motives to their formation on Government Land, both Reserve Forest and Waste Land, should not be allowed to blind the public generally to their immense value. It is conceivable that the Zemindar and large landed private proprietors would in course of time follow an example so set when its value made itself apparent to them.

It has been said that some Provinces, as also Native States, have already taken up and dealt with this matter, and it will be interesting here to see, province by province, exactly what progress has been made towards carrying out the policy of game protection by this means.

III. THE EXISTING GAME SANCTUARIES IN THE COUNTRY.

A. BRITISH INDIA.

I take British India first, and deal with Forest Areas only, which are practically the only areas in which Sanctuaries for game have been formed.

1. *The North-West Frontier Province.*

The only Forest Division in the North-West Frontier Province is that of Hazara, and the Deputy Conservator of Forests in charge says that no Game Sanctuaries have been formed in that Division.

2. *Punjab.*

A number of Game Sanctuaries have been formed in the Punjab, most of the Divisions containing one or more, in which the shooting of certain game is prohibited. Throughout the Punjab a close season is in force in all Reserved and Protected Forests for all game from March 15th to September 15th every year.

Rawalpindi. The Lalachitt, a Reserve, has an area of 93,000 acres. Half of this is closed alternately as a Game Sanctuary for a period of three years. The Barakao plantation of 200 acres is entirely closed to all shooting throughout the year.

Jhelum. In the Jhelum Division there are six sanctuaries entirely closed to shooting. These comprise the Reserves known as Rakh Ara Jadid (12,172 acres), Rakh Samarkand (south, 9196 acres), Rakh Phadial (10,722 acres), Rakh Tilla (24,314 acres), Rakh Nili (south, 17,114 acres), and Rakh Bazza (3742 acres).

Chenab. About 15,000 acres of the Pabbi Reserve and 525 acres of the Thatta Fagirullah Reserve are closed to all shooting.

Kangra. This is a Division with much scattered forest, and a large number of small areas have been made into Game Sanctuaries. A number of these have been closed for forestry reasons rather than directly for the protection of game. However, the results are the same, as they become *de facto* Game Sanctuaries. The game to be protected varies from the hill sheep and goats, oorial, serow, goral, etc., to pheasants, kalig, chukor partridge, kakar (*Cervulus muntjac*), etc. The following is a list of these sanctuary blocks, with their areas in acres:—

Dharant (634), Khanni (698), Tatal (1228), Chatril (1228), Mehdhar (367), Baluhi (312), Swarka (47), Bhali and Dolba (1266), Sildah (266), Ballah (371), Talara Gurial (788), Kalak (256), Mastgarh (240), Tilli (1013), Darang (558), Habrol (480), Gumar (400), Khardwar (123), Lohara (2580), Punjab (3610), Dharni (2822), Karnpur (3321), Bindrahan (2946), Bohan (250), Phakhloh (55), Chagrin and Bhernal (285), Tather (60), Chowkidharin (61), Sariali (61), Tiri (52), Nobian (179), Khalig (56), Jamli (46), Khamahar (378), Baldoa (565), Lohjang (1082), Samlian (537), Tiamal (135), Bakarar (455), Behan (127), Naum (257),

Santhla (403), Saleti (83), Aloh I and II (62), Kandbari (5066), Soupdhar and Pundban (10,831), Boh (7834), Narwana (151), and Chanderban (4484).

Simla. The Division is practically all situated in the hills, the forests being mainly in Native States. The Deputy Commissioner, as Political Officer, issues passes for shooting, which cover everything outside certain specified preserves.

The patch of sal-forest known as Kalesar at the foot of the Simla Hills on the west bank of the Jumna River, area 11,570 acres, is closed to all shooting, as is also the Jagadhari or Kalanour plantation, an area of 197 acres. So also no shooting is permitted in the forests of the Simla Catchment Area. The forests of the rest of the division are open. Kalesar contains sambhar and chital, hog-deer and kakar; the Jagadhari plantation pheasants etc.; and the Simla Catchment Area gural, serow, pheasants, and chukor.

Lahore. The areas closed to shooting in the Lahore Division are mostly plantations. In the well-known Changa Manga plantation of Sissu and Mulberry, situated at about 40 miles from Lahore, Blocks III and XIV (area 4424 acres) are closed to shooting, as is also Shahdara Plantation close to Lahore (1828 acres) and the Shadhanwali Plantation area (3059 acres).

It will be seen from the above that in the Punjab considerable progress has been made in the endeavour to protect the game of the Province.

The game to be protected is nilgai in Changa Manga and game birds etc. elsewhere.

3. *United Provinces.*

Curiously enough, there are as yet no Game Sanctuaries in the United Provinces, and this in spite of the fact that many of the forests are probably amongst the most intensely shot over in the country. It is understood that this question is now receiving the consideration of the Lieutenant Governor and his Conservators of Forests, and it is probable that before long the game of the United Provinces will be given that amount of protection which is essential if its deterioration and disappearance is to be prevented. Were it possible to close blocks of considerable size in shooting grounds like those, *e. g.*, of the Dun (Siwalik Division), there might possibly be some hope of saving the wild animal fauna from extinction; that it is perilously near this, all who are familiar with the conditions and the absurd so-called shooting "rights" these forests are burdened with are well aware.

With Sir John Hewett, the Lieutenant Governor, I would advocate the closing of blocks of forest in every shooting division in the Province for periods of two (I advocate preferably three) years, the areas to be carefully selected and listed and closed and opened in rotation. If an example as to the necessity of this step being taken is required, it is only necessary to compare, say, the Patli Dun with the ruined Dehra Dun forests as an example of what unrestricted shooting, without protection, must lead to.

4. *The Central Provinces.*

As a whole, the Central Provinces may be considered to be the most advanced so far as game protection is concerned. The shooting regulations will be referred to at a later stage. They were revised by the Chief Commissioner in his Notification No. 1263, dated 28th October, 1907. For my present purpose it is sufficient to notice that they provide that areas or blocks of forests may be closed to shooting *absolutely* for purposes of forest management or as *sanctuaries* for the protection of game, other than carnivora, for the destruction of which special permits may be issued. The list of closed forests or blocks is prepared each year in October by the Conservators and is published in the *Central Provinces Gazette*, and copies are hung up in the Deputy Commissioner's and Forest Officer's offices.

It will thus be obvious that the Game Sanctuaries in the Central Provinces are formed automatically by the closing alternately of different forests or blocks of forest yearly. As a matter of fact, however, most of the present sanctuaries, though in many instances reduced in size, have been game sanctuaries since 1902, though a few others have been added later. It would be better if these areas were closed for periods of not more or less than three years. Of course, in the case of areas closed for purposes of forest management it is possible that they are closed for a considerable period of years, but nothing is said on this score in the rules nor as to the length of time blocks are closed for purely sanctuary purposes.

In addition to the automatic closure and opening of blocks there are other most valuable restrictions for the preservation of game, and I believe that I am correct in stating that this procedure is now applied to most of the blocks, instead of automatically closing and opening them. In any particular block or series of blocks only a certain head of any particular species may be shot. As soon as this number has been reached, that species is closed to shooting for the year. This rule might well be introduced elsewhere in the country. It is really better than the procedure of the Nilgiri Game Association of allowing each sportsman to shoot one or two head of each species, since the latter safeguard is in force also in the Central Provinces. The permit of each sportsman is endorsed with the number of head he may shoot, *e. g.* one bison, one sambhar, two chital, four other deer, and carnivora *ad. lib.*, *provided the maximum number of head of the species allowable to be shot in the year has not been already reached.* This latter information is supplied him either by the divisional officer or by the Range officers in the areas for which his permit is made out. Were not this latter provision in force, one sportsman might shoot the whole number of, say, Barasingha (*Cervus duvauceli*) permissible for the year and thus close this particular animal to succeeding guns for the rest of the season—a somewhat unfair and onerous restriction.

In the Central Provinces excluding Berar in 1909 there were 24 Game Sanctuaries with an area of 1445 square miles in the

Northern Circle closed to shooting, but permits could be obtained to kill carnivora, and 293 sq. miles in the Southern Circle, or a total of 1738 sq. miles in the Province.

Other areas are closed conditionally, subject to the issue of a permit or to sportsmen being exempt from obtaining one.

As already stated, the blocks vary from year to year, and the list is made out annually in October and published.

The game protected are bison, buffalo, sambhar, barasingha, and chital, and, in fact, all horned game.

Berar.

The revision of the shooting rules in the Central Provinces in August 1905 was followed by a similar revision in those of the forests of the Berar Circle in the following October, the rule regarding the formation of Sanctuaries being made applicable here. The number of individuals of each species to be shot in a year is laid down and notified. An area of 885 sq. miles was closed to all shooting (save carnivora on permit) during 1909. Shooting in the other forests was subject to permits being taken out in the ordinary manner.

The game to be protected are chiefly sambhar and chital.

Bengal.

Bengal has recently taken up the question of Sanctuaries and under Notification No. 1992 For., dated 6th April, 1907, the following have been formed:—

Darjiling Division.

Senchal Forest. The boundaries of this Reserve are:—

North—Pashok Road from Jore bungalow to the 3rd mile.

East—From the 3rd mile to Lalkhunti where the road crosses the saddle (by the Rangbi path).

South—From Lalkhunti to the old military road.

West—The old military road to Jore bungalow.

Puri Division.

The Bharatpur, Jaimangal, and Majna forests are Game Sanctuaries.

In Angul and Puri the shooting of bison is prohibited.

The shooting of the rhinoceros, buffalo, and female bison is entirely prohibited throughout Bengal.

I would suggest that in certain parts of the Province further Sanctuaries are urgently needed. For instance, the game of the hill forests of Darjiling, Kurseong, and Tista Divisions, especially the two former which are surrounded by planters, requires protection if it is not to be completely exterminated. The Senchal Sanctuary can scarcely be considered sufficient in a country as rugged and difficult as the Himalayas. The plains and forests of both Kurseong and Tista Divisions were once noted for the game they held, but a very different state of affairs now exists and the accounts of old sportsmen are like legendary fables.

On the other side of the Province to the west, the opening out of Chota Nagpur by railway extension has thrown the forests open to a far larger number of rifles than was ever to be seen in that part of India a decade ago or less.

Singblum, Palamow, Hazaribagh. The game in all these forests now requires protection if it is not to be wiped out by the rifles of such large centres as Calcutta etc., now brought within easy rail distance.

Rules such as are in force in the Central Provinces would be equally valuable and applicable to these parts of Bengal.

Eastern Bengal and Assam.

This province may be put almost on a par with the Central Provinces so far as the provision made for Sanctuaries for game is concerned. The work has not been carried out in all the divisions, but the ones most shot over are well provided in this respect, if we except Chittagong.

The provision of Sanctuaries, however, was not made any too soon, if, indeed, it can be considered to have been introduced soon enough. The apathy of the authorities has led to the deterioration of the stock of game almost to the verge of extinction. The forests are in large blocks, and it would have been sufficient in the past to enforce the rules under the Forest Act. Neglect to do so has reduced the numbers of such animals as rhinoceros, buffalo, and bison to such small figures that deterioration, if not extinction, now threatens these species.

The following Sanctuaries exist in the divisions detailed below:—

Khasi and Jaintia Hills. The Riat Khwan Sanctuary of 969 acres in this division is closed to all shooting, with the idea of preserving game in general and not of one or more particular species only. The Laitkar Sanctuary of 432 acres is closed to all shooting, with the idea of protecting insectivorous birds in addition to game in general. The Riat Laban of 995 acres is a sanctuary similar to the Laitkar.

Nowgong and Sibsagar. An immense Sanctuary known as the Kaziranga Sanctuary of 57,273·6 acres is closed to all shooting except permit-holders.

Nowgong. Lowkhawa Sanctuary of 25,760 acres is closed to all shooting, save that allowed to permit holders.

Kamrup. The North Kamrup Sanctuary of 57,600 acres is also closed to shooting other than that allowed to authorised permit-holders.

Goalpara. Three large Sanctuaries have been created at the instance of Mr. W. F. Perrée, Divisional Forest Officer in this Division, probably one of the most visited from outside of any in Assam. The sanctuaries were in the first instance, I believe, designed to prevent the rhinoceros from being exterminated, but the buffalo and gaur are also carefully protected. Although shooting is said to be permitted to permit-holders I believe that, as a matter of fact, these sanctuaries have been entirely closed to all shooting.

The Sanctuaries comprise :—

(i.) Portions of the Raipur and Kachugaon Reserves (area 69,120 acres).

(ii.) A portion of the Raipur Reserve (area 30,040 acres) and a portion of the Bizni Reserve of 36,840 acres.

Jalpaiguri and Baksa Duars. I believe it is intended to form Sanctuaries in these two Divisions, newly acquired by Assam under the Partition. No Sanctuaries have been formed as yet, although they are, we understand, under consideration.

These forests, however, are nominally Sanctuaries already for certain animals, since the shooting of rhinoceros, buffalo, and bison is entirely prohibited. The forest blocks are, however, too small to furnish sufficient space for animals of such wandering dispositions. In former times the animals had access to the adjacent Bhutan Hills in the hot weather, to which they used to repair to escape the fly season. This outlet has now been cut off, owing to the settlements of Nepalis on the Outer Hills.

Chittagong. This is another of the ceded divisions. It might be suggested that a Sanctuary or two should be formed in some of the Reserve Forests in the Collectorate to protect the bison and sambhar, both from the over-keen European sportsmen and the neighbouring villagers, who are apt to help themselves and shoot anywhere. The neighbouring Hill Tracts also afford excellent areas for game protection.

Bombay.

In Bombay the question of Game Sanctuaries has received considerable attention, special areas having been set aside in which only pig, carnivora, and other destructive animals may be shot. To do so, however, entails a special endorsement being first made by the Divisional Forest Officer on the holder's shooting-permit, save in the case of Gazetted Officers whose jurisdiction extends to the Sanctuary in question. Such special permission cannot be given for a longer period than one month in each case.

In the Southern Circle there are four Sanctuaries, situated in the Belgaum, Kanara Northern, Kanara Southern, and Kanara Western Divisions, the areas being 26 sq. miles, 330 sq. miles, 400 sq. miles, and 216 sq. miles respectively.

These Sanctuaries have been specially made to afford protection to sambhar, chital, and bison.

In the Sind Circle a number of Game Sanctuaries have been formed in the Jerruck, Hyderabad, Naushahro, and Sukkur Divisions.

The chief game for which the closure has been prescribed is the "phara." The period for which the Sanctuary is formed is one of five years, at the end of which the Sanctuary will be thrown open and other forests closed.

The Sanctuaries are as follows :—

Jerruck Division.

The Sanctuaries in this Division are eleven in number :—Sonda

(area 2612 acres), Aligunj (1199), Shah Lanko (1743), Garko (4092), Chach (1661), Marho Kotri (1668), Allahbux (2045), Bohadipur (2763), Sukhapur (3878), Hazari (2483), and Shatoh (277).

Hydrabad Division.

In this Division there are fourteen Sanctuaries:—Abad Thebat (640), Rajri Khasai (457), Budhopur Vaechero (748), Railo Bola (1322), Mahomed Khan (181), Kathri (756), Miani (5312), Elchi Hingoroni (288), Nurketi (4254), Kot Dhingano (1893), Kacho Lakha (4705), Mehrobpur (3012), Mari (17,651), Sai (5901).

Naushahro Division.

Fourteen Sanctuaries as follows:—Kocho Khairoders No. 1 (4118), Khairoders No. 2 Phulel and Dulotpur (3570), Lalia (2324), Dalipota (867), Kundoh (5965), Khairodero No. 1 (1650), Ketil Lalia (1159), Karampur (1095), Gajidero (4336), Budhodero (1555), Nari (1522), Kasim Sah (2107), Akil (397), Sharifpur (212).

Sukkur Division.

All the forests of the Sukkur Division have been closed to shooting for five years, as big game (phara) has become scarce. These forests number 64 in all, covering an area of 273,497 acres.

Madras.

Reference has already been made to the excellent Game Association of the Nilgiris. Under the rules of this society, and the spirit in which they are worked out and observed, protection may be said to have reached a high state of perfection in the Ootacamund Hills.

The large resident European population in the hills has, of course, rendered the introduction and strict observance of the rules a much easier business than is likely to obtain in areas which are only visited by occasional sportsmen, who have not even the interest of the local resident officials, who are in a way permanent in the locality, in the upkeep of the head of game, and therefore clamour for free shooting, equal rights, etc.

To some extent the lead of the Nilgiri Game Association has been followed by the Forest Department, but at present apparently only in a small degree.

In the Southern Circle the only Sanctuaries existing in 1906 were situated in the Nilgiri District as follows:—

Nilgiri Game District. The whole Nilgiri Game District was closed to the shooting of pea-hens altogether and jungle-hens for one year. This was done by the Game Association.

Todanad Division. The Marlimund Plantation (17 acres) and the Kanabettri Forest (500 acres of the Segur Reserve) were closed to all shooting.

The Governor's Shola (33), Sheffield Plantation (25), Tiger Shola (20), Kurnutherguli Shola (78), and the Sholas on the east

and south sides of Hembar Hill (36), were closed to small-game shooting only.

South-East Wynad. The Benne (10,344), Madumali (46,639), and the Kombarakkollai (1771) Reserves were closed to bison-shooting for one year from 1st June, 1906. Owing to the heavy mortality, from anthrax, bison had experienced a few years previously and to the increased shooting, this step was a much-needed one; the year could well be extended to three or more.

Kundahs. The Kundah Reserve of 40,379 acres was closed to beating for big game except tigers and panthers, and to the shooting of small game.

Paranginad. A number of Game Sanctuaries have been formed in this Division. In the Longwood Reserve the portion North and East of a line from Kengarai Sign Post to the top of the hill and Longwood No. 1 (30 acres); Nedukaduhalla (885). Sundatti Reserve and addition (123 and 35), Kunshola Nos. I and II (158), Madanad (722) and addition (708), Kodanad valley (294) and additions I and II (245), Nedugula (88) and addition (113), Avarahalla (121), Gudakahalla No. II north of Kilkotagiri bridle-path (70), Seven mile tope reserve (2), Kannerihodai (16), Nlavandmund Shola and additions I and II (118), Sullicodu Nos. I and II (308), Attukadu (71), Warbreccan (17), Sinnattu and addition (358), Uppatti Shola and addition (67), Doddakavu (62), Curzon Valley Block III west of Kilkotagiri-Curzon bridle-path (895). All these are reserves and are closed to beating for big game except tiger and panther; and are also closed to small-game shooting. In addition Rallia (382) and Sims Park (83) are closed to small-game shooting only.

The total area thus closed as Game Sanctuaries in the Nilgiri District in 1906 totalled 107,083 acres.

In the Central Circle only two districts were reported to have constituted Game Sanctuaries.

North Arcot District. In the North Arcot Division various additions to the shooting licenses had been made which will be considered under the shooting-permits. The number of head of particular game to be shot is limited in the case of certain species, as is the case in the Central Provinces. Special sanction has to be obtained for beating; and sitting up over water and salt licks is strictly prohibited.

The following reserves are closed to shooting, without the special permission in writing of the Collector and District Forest Officer :—

Chamala Reserve of 19,142 acres; Javadi Reserve of 403,566 acres; and the Musalimdugu Reserve of 5542 acres.

The game for which these Sanctuaries are especially created are sambhar, deer, black buck in the case of the Chamala Reserve, bison and deer in the Javadi Reserve, and deer and hare in the Musalimdugu Reserve.

In addition, 71 blocks of forest are closed to shooting during the fire season from 1st March to 30th June.

Tanjore District. The Point Calimere Reserve of 4204 acres is closed to the shooting of black buck, chital, and hare. Pigs and partridges may be shot without restriction and three black buck for each license given. All spotted deer, does, and young animals may not be shot between the 1st February and 31st July.

5. *Burma.*

Very little has been done as yet in Burma towards the formation of Game Sanctuaries. Fortunately Burma was but recently disarmed and Government has not given licenses in anything like the numbers granted elsewhere. In many parts game is believed to have increased, but the European sportsman has had little mercy on some species, and the fine herds of brow-antlered deer (*Cervus eldi*) in Lower Burma were almost exterminated before measures of protection were introduced. Deterioration must of necessity follow, even if the species be not entirely exterminated.

No Game Sanctuaries exist in the Pegu, Tenasserim, and Northern Circles.

In the Southern Circle, Upper Burma, the Maymyo Park Reserve was notified as a Sanctuary for game in an interesting notification which appeared on page 421 of the Burma Gazette for the 7th April, 1906. This Sanctuary is in the Mandalay Division, its extent being approximately $7\frac{3}{4}$ miles. The notification being the first of its kind in Burma, it will be of interest to reproduce it here.

"It is hereby notified under Rule 2 (2) of the rules under the Forest Act 1902 that, with the previous approval of the Local Government, the Maymyo Park Reserve is closed to the issue of licenses for shooting or fishing."

The Conservator in issuing a notice on this subject stated: "The object of this is to provide a sanctuary for pea-fowl and other game (chiefly barking deer and partridges) and to thereby enhance the pleasure of the numerous sections of the public who utilize the Reserve for riding and take an interest in the animals therein. It is hoped that the public generally will co-operate with the Officers of the Forest Department in seeing that the intention of the above notification is carried out."

The terms of the notification will not be enforced as regards snipe-shooting in the swamps, which may as heretofore be carried on without license at the proper season, nor will it be enforced as regards the shooting of dangerous carnivora. For the purpose of notification, the following are the rough boundaries of the Sanctuaries:—

North. The Lashio Road from the Circular Road to Yegyano.

East. Bames' ride from Yegyano to Kadettaw cut and the Circular ride from Nyaungni Pagoda to the Mandalay Road near Pwedaung quarry.

West. The Mandalay Road to the Circular road and the latter to its junction with the Lashio Road.

B. NATIVE STATES.

1. *Kashmir.*

Allusion has already been made to the fact that the progressive Native State of Jammu and Kashmir has a Game Preservation Department as a separate part of the administration of the State, with an officer and special staff in charge of the work. This, I think, is the ideal at which British India should, and I believe will, eventually inevitably work up to.

The Department issues each year a printed copy of the Game Laws notification, which are applicable to everyone, save those persons especially excepted by order of His Highness the Maharaja in Council.

The Rules do not apply to the State Game Reserves, for which no shooting-permits are issued.

The existing State Game Reserves, about 300 sq. miles in extent, are:—

(1) Chashma Shahi, and (2) Dachgam, and the ridge of hills between these Rakhs, (3) Khonmoo, and the grass-farm between Sangri and Chak Khonmoo, (4) Khru, (5) Tral-cum-Kerrim, and Punjhair as far as the Bhoogmor Road, (6) Achabal, (7) Koolgam, (8) Kandi and Khoras in the Uri Nullah, the lower boundary of which is the new road to the Hajipir and Hokarsar Jhil.

N.B.—The basin above Pandrittan is a Sanctuary for chukor.

In General Raja Sir Amar Singh's Jagir and in the Ilaqua of the Raja of Poonch no one is allowed to shoot without the permission of the respective Rajas.

The following Nullahs will be considered as the private shooting-grounds of their respective Rajas, viz., Kapalu, Khar-mung, Shigar, Rondu, Kiris, also that portion of the Mantho and Satpur Nullahs demarcated in 1905, for the Rajas of Tolti and Skardu, respectively. These nullahs will be closed for shooting, except with the permission of the Rajas concerned.

The following Nullahs are closed until further orders as Game Sanctuaries, and no shooting is permitted therein, nor is any grazing allowed:—

I. The Cretchen basin in the Lidder Valley from Bhatkote to Kitchroo (Srinagar Khass). Area 20 sq. miles.

II. The Kiar Nullah in the Duchan District of Kishtwar. Area 120 sq. miles.

III. The Gueo Nai in the Wardwan (Kishtwar). This is the nullah which joins the left bank of the Wardwan River one march above Maru Wardwan. Area 48 sq. miles.

IV. and V. Nimo and Masho in Ladakh. Area 40 and 36 sq. miles.

VI. Melangan in the Kajnag (Mozufferabad). Area 28 sq. miles.

VII. The Siranda branch of the Erin Nullah (Baramoula). Area 32 sq. miles.

VIII. Alchori and Hashopa and intermediate ground in the Shigar Valley (Baltistan). Area 50 sq. miles.

IX. Doosoo in the Nowboog district (Srinagar Khass). Area 60 sq. miles.

X. Shelter in Astor. Area 30 sq. miles.

XI. Soomjam and the Sapphire Mines Nullah in Kishtwar. Area 35 sq. miles.

XII. Gabdoori and Kunirawul in the Shamsheebiri. Area 23 sq. miles.

As will be seen when we come to a consideration of the shooting rules in force, driving game is only permitted in certain localities at certain periods, the number of head to be shot on a license is restricted per species and neither females nor young may be shot.

2. *Chamba.*

Chamba is another of the favoured shooting grounds of the European from the climatic point of view, and under the late Raja the game was being rapidly destroyed. Under its present enlightened and most hospitable ruler conditions have altered, and shooting is now prohibited save on permits issued by the Raja himself.

Sportsmen have found little difficulty in obtaining such, the ground and number of head to be shot being indicated on the permit. The method of protection followed is on the lines of the Kashmir Shooting Regulations.

3. *Hyderabad (Deccan).*

Whilst there are no special Game Sanctuaries in the Hyderabad State Forests, the recently amended Game Regulations and the periodical opening and closure of certain tracts to shooting go to prove that His Highness the Nizam is fully aware of the necessity of affording protection to the wild game of his territory if it is not to be exterminated by over-shooting.

The Game Preserves of the State are of four classes:—

I. *His Highness the Nizam's own Preserve.*—This Preserve is situated in the Warangal Division in the neighbourhood of the Godavery Valley Railway, and has an approximate area of 828 sq. miles. Protection in this Preserve is provided to all game, and the shooting in this tract is reserved entirely for His Highness the Nizam or His Excellency the Minister. No permits to shoot can be obtained.

II. *His Highness the Nizam's State Preserves.*—These are situated in the vicinity of Yellander and Singarein. All game is protected, and permission to shoot can only be obtained from the Nizam or his Minister. This area is kept for the State guests,

and a permit would never be granted under ordinary circumstances to the casual sportsman.

III. *The Open Forests*.—The Open Forests are divided into three Divisions. These are opened each year from 1st March to 31st July and for ten days at Christmas in rotation, *i. e.* each division is open for one year and closed for two. The divisions are each divided up into separate blocks. Sportsmen wishing to shoot in any special block register their names, together with a fee of R. 25 before the 1st December. The names of persons applying for the blocks, in the event of there being more than one, are publicly balloted for by lot on a date fixed somewhere about 1st January and the permits are issued accordingly. Persons drawing a block pay an additional fee of R. 25 for each member of the party intending to shoot. Those failing to draw a block are refunded their deposited fee.

Anyone not occupying his block within a month of March 1st may be made to forfeit his right to do so, in which case the block is given to the next name drawn.

Priority of claim to an open block is always allowed to a person resident within H.H. the Nizam's territories.

The number of tigers allowed to be shot in a block is limited to a total average of two per each rifle in the party.

Deer are not, and never have been, protected in any way, and as nearly every person in the State is armed with a firearm of some sort, from the latest thing in Rigby cordite rifles to a horse-pistol, practically the only game existing outside the State Preserves is confined to carnivora and bears.

IV. *The Jaghirs*.—Jaghirdars have the right to give or refuse shooting-permits to applicants to shoot in their land, as they think fit. For others permission to shoot in a Jaghir is a private matter between the sportsman and the Jaghirdar.

4. *Pannah State* (Bundelkhand).

In the Pannah State there are two State Sanctuaries of about 50 sq. miles apiece, which have existed from time immemorial. No one is permitted to shoot in these, save the Maharaja and the Political Agent, so that they are not Game Sanctuaries in the true sense of the word. The license granted for shooting in other parts of the State prohibits the killing of tiger, chital, stag, sambhar (when hornless or in velvet), and doe sambhar throughout the year.

In a letter answering some enquiries put to him on the question of Game Protection in the Central India States, Mr. R. M. Williamson, I.F.S., who has a considerable experience of these States, wrote:—"Generally there is no protection of any sort of game outside the special State Preserves, except tiger, the killing of which is reserved for the ruler. This state of affairs is general in the Native States of Central India, and it is impossible to effect any improvement in this respect till additional forests are reserved

and brought under efficient protection. My experience both here (Rewah) and in Bundelkhand is that big game (save carnivora) is much scarcer than in British Indian Forests, *i. e.*, that the proportion of carnivora to other kinds of big game is far higher in these States than in British India."

5. *Bhopawar Agency.*

No regular Game Sanctuaries have yet been formed in the Bhopawar Agency, but the Game Rules are undergoing revision, and with this revision the formation of Sanctuaries is intended. A close season is in force, but it does not extend to solitary bison, stag or male antelope, florican or quail.

6. *Rewah State.*

Shooting of all kinds is prohibited in the Reserved Forests without special permission, which it is very difficult to secure. The area of the reserves totals, however, only 600 sq. miles. Elsewhere there is no game protection whatsoever for game, save tigers, the shooting of which the Maharaja reserves for himself and his guests.

7. *Cochin.*

The Conservator of Forests of the Cochin State informs me that no Game Sanctuaries have as yet been established in the Cochin State.

8. *Mysore.*

In Mysore seven areas have been set aside as Game Sanctuaries. No special rules have been framed for these areas, but the protection of bison, sambhar, and other deer is chiefly aimed at. It is apparent, however, that shooting is allowed in the areas, but only with the special permission of H.H. the Maharaja.

It seems a pity not to prohibit all shooting so long as an area is a sanctuary and to rotate the sanctuaries on a three or five yearly system.

These sanctuaries are situated as follows:—

1. *Mysore District.*—This District contains four sanctuaries, Kakenkote, Begur, Berambadi, and Chamarajanagar, of 55, 42, 102, and 98 sq. miles in area respectively.

2. *Hassan District.*—One Sanctuary, by name Hirikalgudda, of 27 sq. miles in area.

3. *Kadur District.*—One Sanctuary, Tegurgudda, of 9 sq. miles in extent.

4. *Shimoga District.*—One Sanctuary, Sakrebyle, of 15 sq. miles in area.

9. *Travancore.*

There are no Game Sanctuaries in Travancore, and none are considered necessary. The Conservator of Forests writes: "There are no Game Sanctuaries in the Travancore Forests, nor are they considered necessary, because the area of evergreen forests where

the game can take refuge is so extensive that there is no danger of its extermination. In the Reserved Forests extending over one-third of the State, hunting and shooting are only permitted after a license has been obtained."

IV. THE PROPOSED INDIAN GAME ACT.

I shall now briefly glance at the provisions of the New Indian Game Protection Act.

The following is an abstract of the Proposed Indian Game Protection Act :—

1. (1) To be called the Game Protection Act.
- (2) Includes all India, Baluchistan, Santhal Parganas, and Spiti.
- (3) To come into force when published in the Gazette of India.
2. "Game" and "large animal" to have meanings defined by Local Governments. In the absence of such definitions they shall mean :—
 - (a) Game : The following in their wild state :—
 - (I.) All pigeons and sandgrouse.
 - (II.) Peafowl, jungle-fowl, pheasants, partridges, quail, spurfowl, florican, and their congeners.
 - (III.) Geese, ducks, and their congeners.
 - (IV.) Woodcock and snipe.
 - (V.) Hares.
 - (VI.) Asses, all kinds of rhinoceros, buffalo, bison, oxen ; all kinds of sheep, goats, antelopes, and their congeners ; all kinds of gazelles and deer.
 - (VII.) Any other animals the Local Government may notify.
 - (b) (I.) "Large animal" shall mean any animal included in subclause (VI.) above.
 - (II.) "Specified kind" means any kind of game, large animal, or fish, distinguished by species, immaturity, or sex.
3. This Act does not affect :—
 - (a) The pursuit, capture, or killing of :—
 - (I.) Game by non-commissioned officers or soldiers, on whose behalf regulations have been made.
 - (II.) Any animal for which a reward may be claimed from Government.
 - (III.) Any large animal in self-defence.
 - (IV.) Any large animal by a cultivator or his servants, whose crops it is injuring.
 - (b) Anything done under license for possessing arms and ammunition to protect crops, or for destroying dangerous animals, under the Indian Arms Act (XI. of 1878).

PROHIBITORY PROVISIONS.

4. No firearms shall be used or carried for killing game, without license under this Act, or under the Indian Arms Act.
5. The Local Government may, by notification, prohibit, within any local area, for any period, the capture, or killing, or attempt to capture or kill :—
 - (a) All game, or any specified kind.
 - (b) All game, or any specified kind, by any special means or manner, either absolutely or except in accordance with a license under this Act.
6. (1) The Local Government may prohibit the capture or killing (or attempt to capture or kill) of any fish, during any part of the year, in any specified stream, or in the headwaters of any specified river, or in any specified part thereof.
(2) Any notification under this section shall be conclusive proof of the matters stated therein.
7. A Local Government may notify prohibition of the possession or sale of all game or fish, within Municipal or Cantonment limits, or in the importation of any kind of plumage of any specified kind of game.

PROVISIONS AS TO LICENSES.

8. (1) Licenses shall be granted under this Act, by authorities empowered under it, save as provided under subsection (2).
(2) A Local Government can authorise a Commissioner or, in Madras, the Collector, under orders of the Governor-General in Council, to grant licenses under this Act, for the use or carrying of firearms for killing game, throughout the whole of British India.
(3) Under rules framed by a Local Government, the Collector, or any authority thereby empowered, may cancel any license granted under this Act :
 - (a) When the holder has been convicted under this Act.
 - (b) When any term of the license has been infringed.
9. (1) In addition to conditions prescribed by a Local Government, every license shall be deemed to be subject to the conditions set forth in any notification in force for the time being under section 5.
(2) Every license shall specify :—
 - (a) The area in which it is in force.
 - (b) The instruments to be used, and in the case of a weapon to which the Indian Arms Act (IX. of 1878) applies, the person or persons by whom alone it may be used or carried.

- (c) When the license is so restricted, the specified kinds of game, the periods, and the methods of capture or killing, to which alone it is to apply.
 - (3) When firearms are authorised, the license may limit the number of any specified kind of large animal which may be killed, and the fee payable for each such animal killed.
 - (4) Every such hunter, beater, or assistant, aiding the licensee, shall be protected by such license.
10. Every license under this Act is non-transferable, and may be granted for any period not exceeding a year, and may be renewed on payment of a fee of twenty rupees for each issue, and for renewal, provided :—
- (1) That the Governor-General may notify a higher rate of fee in the Gazette of India, and that security shall be deposited on each issue or renewal, or from any specified class of persons.
 - (2) That a fee of only five rupees be payable by an owner of agricultural land ; the license to be in force exclusively within the village or villages in which such land is situated, and within a local area, if it includes more than one village, not exceeding fifteen hundred acres.
 - (3) That a Local Government may exempt any specified class of person, in any specified area, from payment of fees on licenses not authorising the use of firearms.
11. Every licensee is bound :—
- (a) to produce his license for inspection, when demanded, by any Magistrate, Police officer not below the rank of Inspector, or in a forest by any Forest officer not below the rank of Extra Assistant Conservator ;
 - (b) to deliver up his license on expiry of the period for which it was granted, or when leaving India, whichever is sooner, to the Collector or any authority authorised to grant a license, or to the principal Police officer of a district.
12. Every licensee shall :—
- (a) keep an account of any specified kind of large animal killed, giving sex, date, and place ;
 - (b) produce such account on demand made by any Magistrate, Police officer not below the rank of Inspector, or in a forest by any Forest officer not below the rank of Extra Assistant Conservator ;
 - (c) deliver up such account, and his license, on expiry of the period for which the license was granted, or on leaving India, whichever is sooner, to the principal Police officer of the District or Presidency town in which he then is.

13. (1) A licensee under this Act is exempt from the provisions of the Indian Arms Act as regards taking out a license for the same weapon, and the same area, under that Act.
- (2) Every license granted under Forest regulations for the capture or killing of game, shall have the same effect as a like license granted under this Act.

RULES.

22. (1) A Local Government may make rules for the purposes and objects of this Act.
- (2) Such rules may :—
 - (a) declare the authority by which the licenses may be granted or cancelled ;
 - (b) prescribe terms and conditions under which such licenses are granted ;
 - (c) provide for appeals from orders made under the Act, otherwise than by a Magistrate or Court.

V. SOME CRITICISMS ON THE PROPOSED ACT.

It will be of interest to consider in some slight detail several of the provisions of the proposed Act.

The Provincial Rules at present in force under which all Game Protection work is carried out are comprised in the Arms Act, Forest Act, and Fisheries Act.

The proposed new Act extends to all India, with the exception of Burma and, of course, the Native States. I have shown that some of these latter are already doing excellent work in Game Protection, and others will doubtless follow a firm lead set them by the Imperial Government.

It is not intended here to offer any seriously destructive criticisms on the above provisions of the suggested Game Act.

There are one or two points to which, however, I think attention might with advantage be drawn. In the second clause the meanings attached to "game," "large animal," and "bird" are distinctly and regrettably vague. I am unable to see any reason for this. If the drafters of the Bill were to apply to any zoologist in the country who has a practical working and sporting knowledge of the game life of India they could be furnished with detailed lists of animals both large and small : and by "animals"

I here mean "mammals" classed, say, into some such groups as, *e. g.*,

- (a) *Carnivora*. Each species in the country to be quoted.
- (b) *Herbivora*. do. do. do. do.

The various deer, antelope, goats, and sheep are all perfectly well known, and the preparation of lists detailing each animal by name is an absolutely easy matter.

(c) *Rodentia*. Including the hares, porcupines, etc., the total extinction of which from a sporting point of view is far from desirable.

(d) A *General Group* which may be made to include the rest of the *Mammalia*. This would allow protection to be extended, should it be deemed necessary from the point of view of the preservation of the species in the case of rare species now perhaps being exterminated for the value of their fur or for other reasons, to animals not at present included in the sportman's category of Game.

Turning to the Birds. There is no distinction made between migratory birds and non-migratory birds, and no mention made at all of *Insectivorous* Birds, and yet the distinction is one of enormous value in a great agricultural country like India, where the benefit the cultivators must derive annually from insectivorous birds is quite incalculable.

I suggest that the Birds be sharply defined into groups and the names of all the game-birds and of all the chief insectivorous birds be definitely given in the Act. This likewise is a matter of the greatest simplicity, since there would be no difficulty in drawing up such lists.

With a proper classification by name of all our animals and birds, sections and subsections 2 (a) (I.) to (VI.) would be revised and (VII.) and (b) (I.) and (II.) could be eliminated if considered necessary.

Turning now to section (3). Allowing that it is necessary to make separate rules for the Army, I think that the Act should specifically lay down that permits may not be given for parties of more than say 4-6 men from a cantonment to go out *together* to shoot in any area. At present it is well known that at times parties of from 15 to 20 or more men go out into a block of forest and drive the game systematically into a *cul-de-sac* and then slaughter the animals in numbers. The Gurkha is particularly addicted to this form of "sport" during the rainy season, when in the parts of the country where they are cantoned it is generally impossible for the European to go near the Terai forest owing to its great unhealthiness. Parties of military men should be small and the number of head they may shoot should be distinctly laid down on the permit, and penalties be enforced if this number is exceeded.

I think the Game Act might embody some such definite ruling for the whole country.

3. (II.) I am of opinion that Game rewards in general should be abolished and that no provision on the subject should be included in the Game Act.

It would be quite within the power of the Local Government to

issue rewards for the destruction of a particular species which is on the increase and becoming a danger either to public life or property or to the sporting interests of a particular area of country.

Also, save in exceptional cases, *e.g.* rogue elephants and man-eaters, I would abolish the giving of a reward for *every* tiger, leopard, wild dog or wolf slain.

Where any of these animals were becoming a pest or scourge to the community or endangering the head of game of other species in any locality, the Local Government should notify or empower its officers to notify a reward or scale of rewards to remain in force until the danger is past and the balance of power between man and animal or animal and animal is once again normal. The rewards on the prescribed animals should then be taken off.

Every shooting season nowadays sees an army of eager sportsmen competing for blocks and shooting-permits, and surely the giving of the old-time reward for a tiger is quite unnecessary. I would leave the grant of rewards or offer of rewards to the discretion of the District officer or Forest officer. They would when necessary prescribe such and such an animal to be a man-eater or cattle-lifter of notoriety and would fix a reward upon the animal, procuring, if considered necessary, the sanction of the Commissioner or Conservator to their doing so. Why Government should nowadays pay a reward of from Rupees 20 to Rupees 50 for a tiger which may be a pure game-eater and rarely if ever touch a cow (and there are numbers of such) is beyond my comprehension. Sportsmen will not slack off if the rewards are withdrawn. Many a district official would be only too delighted if they would. Once a man-eater or a noted cattle-lifter is proclaimed, then make it worth the sportsmen's while to collect to tackle him by giving straight off a large reward commencing at R. 200 and going rapidly up to R. 500. It would be a far more satisfactory way of working the reward system both from the point of view of the cultivator, the man who lives on the soil, and that of the sportsman, and, I think, would probably be less costly to Government.

Or rewards might be offered only for tigers in a district or parts of a district where a noted man-eater or cattle-lifter has made his home. For every tiger killed in this area a suitable reward might be given, say R. 50, with the larger reward to be paid to the sportsman who bagged the particular man-eater or cattle-lifter prescribed. This would probably be the best method, since it would tempt sportsmen to have a try for the man-eater, knowing that they would receive a certain reward for each tiger killed, even if they should not be lucky enough to kill the prescribed beast.

VI. SOME SUGGESTIONS FOR THE PRESERVATION OF THE GAME OF THE COUNTRY IN THE INTERESTS OF THE GAME ITSELF AND OF THE SPORTSMAN.

The maintenance of a proper head of a particular species on the areas it affects in the country, *i.e.*, in its own particular habitat,

is the first point for consideration, as we elsewhere mentioned, in the interests of the preservation of the species from

- a.* Deterioration,
- b.* Extinction.

The first point to be considered to ensure this object being attained is the question of close seasons.

It is not of advantage, as was done in many Presidencies and Provinces, to divide the year into two periods, calling one the close season and the other the open and apply them to all animals alike. Such a policy in a country of such varying conditions and climate as India is obviously not only inadequate but may do as much harm as good, for the breeding-seasons of many animals and birds vary totally from those of others, whilst some species breed at one time in one place and either later or earlier in other parts of the country. Take, for instance, the three chief deer in the Central Provinces (sambhar, barasingha, and chital). Of these the sambhar sheds its horns the earliest in the season (late April), the barasingha next, and the chital last, the latter a month or two, or more, later than the sambhar.

The close season for one obviously commences earlier than does that for the others. At the same time I am not prepared to say that the close season for sambhar in the Central Provinces would be the same for the United Provinces Terai or for the Assam Forests.

The drawing up of the close seasons for both animals and birds is a work for the Local Government. With the knowledge we now have of their habits, the preparation of such memoranda presents no difficulties whatsoever. For instance, in the Central Provinces Shooting Rules excellent Appendices are given in which the varying dates for the close seasons for the game-birds of the Province are laid down.

In drawing up the close seasons, therefore, I would prepare tables showing separately the close season for each animal and each game-bird of the Province. I also suggest that a separate Appendix be attached to the Shooting Rules giving the names of the insectivorous birds of the Province and enlisting the sympathies of all sportsmen in their protection. A list of the small predatory mammals and predatory birds such as hawks could also with advantage be attached to the Shooting Rules, with a recommendation to sportsmen to shoot such pests when met with. There appears to be little danger at present of their numbers decreasing to a dangerously low figure, and their depredations touch the cultivator in one way, though not perhaps such an obvious one, almost as closely as those of the large carnivora.

Having disposed of the question of the proper drawing up and enforcement of the correct close season for each particular species of animal and bird, we now come to a consideration of a question which is of almost equal importance.

In past years but scant attention has been paid to the severe attacks of a disease having kindred affinities to anthrax which

appears at intervals and takes a heavy toll of the head of game (such as bison (gaur), buffalo, sambhar, etc.) on the area it affects.

Further, in years of severe drought the mortality amongst the wild animals of the country affected is often very heavy, and in the past this factor has received no consideration from the authorities in the interests of the wild game.

I suggest that in the wake of such calamities a very careful and detailed inspection of the area or areas affected should be undertaken, with the object of ascertaining which species have suffered and to what extent. Until such survey has been carried out, no shooting-permits should be issued for the area or areas. After the survey the species which have suffered severely should be notified, as also the area affected, and this area should be entirely closed to the shooting of these particular species for such period as will ensure their multiplication to the number of head it is required to maintain on the area. In closing such area the notification should distinctly state the reason for the closure. No true sportsmen would be found to cavil at such a procedure.

The period of closure would require careful consideration. I remember reading a year or two ago that the Nilgiri Plateau was closed to the shooting of sambhar for *one* year. There would seem to be little use for such a procedure, as no growth of horn of any value to a sportsman can be put on by a stag in a year. Of course, such a provision might be of use in the case of areas which are repopulated from neighbouring forests outside the limits of the area for which the provisions are in force, and this may have been the object on the Nilgiri Plateau. Still it should be borne in mind, I think, that it is of little use closing areas or closing the shooting of particular species unless the time that species will take to produce the desired result is carefully taken into consideration. And nowadays such knowledge is available, since we have a first-rate working knowledge, thanks to many enthusiastic and hard-working sportsmen, of our game animals and birds.

In the case of an area affected by anthrax, for example. It would be necessary to close the area to the shooting of the decimated species for such a period as would allow a two-year old sambhar stag to produce a decent head, *i. e.* from 4-5 years. For bison or gaur the period would be longer, and so on. Sportsmen may decry this suggestion and say that it is too strict. But why? The true sportsman, I take it, only wishes to shoot good heads. Supposing, for instance, one or two good sambhar heads only are left in an area. Only a man or two can get them. A sportsman may follow who has come expressly to the area to obtain a good sambhar. The anthrax attack was unknown to him. The result is that he wastes both his time and money, and has a very good complaint against the District Officials, who he very rightly considers should have notified that the area contained no good heads or, as we suggest, should have closed it to shooting of this species.

Some three or four years ago anthrax swept through a part of the Central Provinces and portions of Madras, resulting in a heavy mortality amongst the wild game, especially bison and

sambhar. I know of one or two recent cases where men coming from a long distance have taken blocks of forest in these areas, not knowing of the anthrax attack. Take the one animal, sambhar. One or two decent heads were bagged, but after that the most indefatigable and laborious search, both in plain and hill forest, resulted only in the disclosure of the fact that though young 2-3-year old stags were numerous, large ones were almost absent. It may be said that this in itself acts as an automatic closure. But it does not, as there is a considerable number of sportsmen who will shoot the smaller head, as an examination of trophies in the bungalows of every station in India will only too clearly disclose. The entire closure of the species to shooting after such visitations is the only fair action to take, both in the interests of the animal and of the sportsman.

And now to turn for a moment, in conclusion, to the question of the sportsman—the outside sportsman, not the District official—and the rules under which he can enjoy sport in a district.

The rules under which the District official enjoys sport in his district are, I think, quite fair in most if not all Provinces.

I think, however, that the outside sportsman has often a justifiable complaint, though more often than not he goes the wrong way about in making it, and so puts himself out of court.

The whole matter really turns, and must always turn, on the number of individuals of a particular species it is permissible to shoot on a given area. This number can only be fixed by the District Officers on the spot. There can be no cavil against this, as they are, or ought to be, the best judges on the question.

In fact, as matters in game protection at present stand, and in the absence of a separate Game Protection establishment, there can be no appeal from their decision.

Probably the best and most elastic method for the outside sportsman is to give him a block or blocks, according as to what is available on receipt of his application, and to enter on his permit the number of individuals of any one species he may shoot and the number of different species. This number would, of course, vary according to the length of time for which the permit was issued, but would never exceed a fixed maximum for each species. So far so good.

But it will doubtless soon be found necessary to definitely limit the number of head of a species to be shot in any one area in a year, as is done, in fact, in the Central Provinces. It is in this limitation that complaints arise and causes for friction come in.

For instance, supposing twelve sambhar may be shot in any particular block. A military man, whose leave season will not open before the 15th April, applies for and is allotted a block. He arrives to find the maximum annual number of the animal it is permitted to kill already reached and is debarred from shooting that particular species. It is quite conceivable that he might find more than one species in the same condition. In fact, the total number of head of a particular species might be easily shot off by the local District officials in the first couple of months of the open

season, the animal becoming then *de facto* closed to shooting for the rest of the open season.

This is where the shoe pinches the heel of the military man very hard, as also, of course, that of his civil brother when shooting on areas outside of his jurisdiction. To remedy a state of affairs which is undoubtedly a real grievance, I suggest that the number of individuals to be shot in a particular block or area in any one year should be allotted in a fixed proportion *throughout each month of the close season* for that animal, say 2 or 3 or 4 per month, according to the total number notified as shootable during that season, any balance remaining from any one or more months being, of course, carried forward and distributed throughout the remaining months of that shooting-season.

This would give the hot-weather military sportsman, who in pursuit of his favourite pastime is ready to put up with many and decided discomforts, an equal chance with his civil brother, who is not so tied during the cold weather. The suggestion is made simply with the idea of giving a fair chance to all.

But I would suggest a further step. I would allot a certain proportion of the head of a particular species to be shot in an area to the local District officials, the balance going to the outside sportsman. The District officials could be left to make their own arrangements as to when their proportion of head was to be shot, but I think that in the case of the outside sportsmen the number to be shot should be allotted throughout the shooting months, so as to give an equal chance to all the block-holders.

No reflection is intended on the District officials by any of these suggestions. They are made only in the interests of that particular quality all Englishmen pride themselves in possessing—Fair Play.

4. On the Moulting of an Arctic Fox (*Vulpes lagopus*) in the Society's Gardens. By R. I. POCKOCK, F.R.S., F.L.S., F.Z.S., Superintendent of the Gardens.

[Received October 24, 1911: Read November 7, 1911.]

(Text-figures 6-13.)

The following account of the seasonal change of colour and the phases in the moult of an Arctic Fox (*Vulpes lagopus*), which had been living in the Society's Gardens since 1904, is based on observations made during the summer of 1906.

The white winter coat was retained unchanged until the middle of May. In the latter half of that month it began to come off on the outside of the fore and hind legs, on the back of the ears, on the muzzle, and on the sacral region in front of the root of the tail. By the end of May the sacral patch had extended as a narrow strip down the thigh, joining the moulted area on the outer side of the lower portion of the leg. The hair was thinning on the back of the head, and as the white coat parted with the movements of

Text-fig. 6.



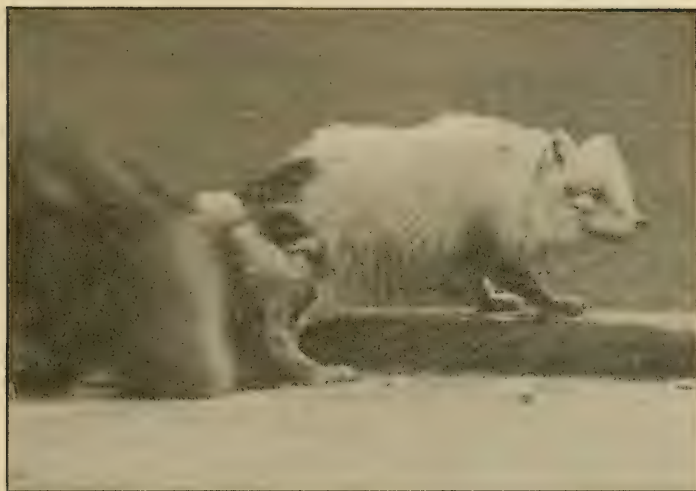
Arctic Foxes showing the persistence of the thick coat in both "white" and "blue" varieties until the early summer. May 5th.

Text-fig. 7.



Arctic Fox showing the beginning of the moult. June 5th.

Text-fig. 8.



Arctic Fox showing the shedding of the white coat over the hind quarters.
June 15th.

Text-fig. 9.



Arctic Foxes, the white specimen showing the further shedding of the coat over
the hind quarters and along the back. June 18th.

Text-fig. 10.



Arctic Fox showing the shedding of the white coat along the back. June 18th.

Text-fig. 11.



Arctic Fox showing the white coat adhering to the tail, to the throat, and to the sides of the body. June 21st.

Text-fig. 12.



Arctic Fox with moult nearly complete, the white coat still adhering to the tail, but on the body reduced to a small patch behind the shoulder. July 5th.

Text-fig. 13.



Arctic Fox with the dark coat almost entirely replaced by the new white coat. October 16th.

the animal, the dark summer coat could be seen beneath. This condition lasted until about the middle of June. The change thereafter proceeded more rapidly. The coat was moulted all along the middle line of the back from the root of the tail to the nape of the neck. It then came off on the sides of the neck, the shoulders, and the belly, leaving a white mat on the throat, the sides of the body, and tail. By the end of the first week of July the patches on the throat and on the sides were much reduced, but the tail was still white. By the middle of July the animal was in full summer coat. The summer coat lasted without clearly marked change for about two months only, but, owing to the gradual nature of its transition to the winter coat, it was not possible to state exactly when the change began. Like the winter coat, the summer coat was moulted. It did not, however, come off in tufts, but was gradually replaced uniformly all over the body, the first indication of the replacement being an apparent increase in the thickness and paling in the colour of the summer coat. To ascertain that the summer coat was really being shed, it was found necessary to catch the animal, when by pulling the coat it was found that the dark hairs were coming away.

The changes in the colour and coat of this animal were watched for several years after 1906, when the photographs were taken, and practically no variation in the details of the process or in the time of their occurrence was observed.

In a blue variety of the Arctic Fox which lived for several years with the one above described, the coat was shed in the same way and at the same time as in the other, but there was no change of colour except such as accompanied the replacement of the faded winter coat by the darker-tinted new summer coat. For neither of these specimens was the locality known; but several specimens of the species from Hudson's Bay that the Society possessed in 1910-1911 turned white in the winter.

I am indebted to Mr. P. W. Farnborough, F.Z.S., for permission to reproduce the unique series of photographs illustrating the facts recorded in this account, with the exception of text-fig. 13.

5. On the Moulting of the King Penguin (*Aptenodytes pennanti*) in the Society's Gardens. By DAVID SETH-SMITH, F.Z.S., M.B.O.U., Curator of Birds.

[Received October 21, 1911: Read November 7, 1911.]

(Plate I. *)

Under the above title Mr. W. E. de Winton published a paper in 1898 † in which he described the moult of a specimen of *Aptenodytes pennanti*, which the Society at that time possessed, the only previous paper on the moult of Penguins being one on the change

* For explanation of the Plate see p. 62.

† P. Z. S. 1898, p. 900.



1.



2.



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4.



5.

Photos by D. Stead Smith.

MOULTING OF *APTEMODYTES PENNANTI*

from the immature to the adult plumage of Humboldt's Penguin (*Spheniscus humboldti*) by the late Mr. A. D. Bartlett*.

I propose to supplement these papers with some observations I have made on the moult of a King Penguin recently acquired by the Society.

The specimen observed by Mr. de Winton did not moult until it had been in the Gardens some sixteen months, when it began to look "seedy," the feathers losing their lustre and the bird sitting moping with half-closed eyes. This state of things went on for fully a month before any feathers were shed. When it began to moult the feathers of the back and wings became "as brown as withered leaves, so that the bird looked as if it were covered with mud." The tail-feathers were the first to be shed, and it was observed that the bird assisted the removal of the feathers by pushing them off with its beak. This moult took place in August–September and occupied about a month.

The example from which I have taken my notes was presented to the Society by Señor Clemente Onelli, and arrived at the Gardens on February 11th, 1911, since which date it has gone through two complete moults, the first in March, and the second in August–September. The moulting of this species seems to be very irregular in captivity. The bird observed by Mr. de Winton arrived in the Gardens in June 1897, but did not begin to moult until August of the following year. It lived until January 1903, but did not repeat the process of moulting, its plumage gradually fading to a sandy-brown colour, so that when two new birds were received in 1902 they were hardly to be recognised as belonging to the same species. Our present specimen has, as before mentioned, completed the process twice in six months.

This irregularity is doubtless due to the changed climatic conditions under which the birds live here. In all probability they normally moult once during the year, but on this point we have no evidence. On both occasions upon which our present specimen has moulted here, the process was completed in just four weeks. In neither case did the plumage appear faded to any appreciable extent before the moult, the feathers being merely somewhat dirty and stained with fish. Before moulting the bird took an extra quantity of fish, devouring as many as fifteen herrings a day, but just before the moult commenced its appetite failed and it was with difficulty that the keeper persuaded it to take even one fish a day. The bird began to look very puffed out all over and its eyes became dull.

The tail-feathers were the first to be shed, and the feathers began to come off from the lower regions generally and the process to be gradually continued upwards. The undersides of the wings, however, were clean moulted at an early period.

It was observed that the feathers were not shed easily, but had

* P. Z. S. 1879, p. 6.

to be helped by being pushed off by the bird's bill, or scratched off with the feet. The new plumage was apparently fully grown before the old feathers were shed, this giving rise to the very puffed out appearance of the bird just before the actual feather-shedding commenced. The throwing off of the old plumage proceeded gradually in an upward direction, and when it had been going on for about a fortnight the bird presented the appearance of wearing a cape (Pl. I. fig. 1), the lower regions being clean-moulted while the old feathers still adhered to the upper parts. The bird continued to rub off the feathers where it could reach them with its bill, the continual moving of the head and neck causing those on the throat to fall off and leave a triangular patch of the new plumage visible.

Bartlett noticed that in the case of *Spheniscus* the feathers of the flipper-like wing flaked off in masses, and I took particular notice of the King Penguin to see if the same phenomenon occurred, and with the aid of the keeper, Pace, was able to secure a clump of shed feathers which had come off *en masse* from the wing (fig. 2). The feathers on the forehead were pushed up into projecting ridges, which can be seen in the photograph (fig. 1), by the new plumage and probably flaked off in a mass, though we were unable to find them. Most of the feathers of the head and neck were, however, scratched off with the bird's feet, the photograph (fig. 3) showing the process of removing these feathers. Figures 3 and 4 show the bird nearly clean-moulted, patches of the old plumage remaining only on the back of the head, the chest, and the back, parts that could not easily be reached with the bill. Those on the head were finally scratched off with the feet, but how the others were removed, or whether they actually fell off finally without assistance, is uncertain.

The appearance of the shed feathers (fig. 5) is remarkable, the main shaft being extraordinarily broad and flattened out like a scale. The stem is bent away from the shaft almost at right angles, and to the end of the shaft is affixed the sheath of the new feather which, in growing, has pushed off the old. This accounts for the fact of the feathers failing to fall off easily, but having to be helped off by the aid of the bird's bill or feet. The two feathers at the top of the figure are from the tail, the bottom one from the back, and the others from the abdomen.

EXPLANATION OF PLATE I.

Moult of the King Penguin (*Aptenodytes pennanti*), from photographs taken by the author.

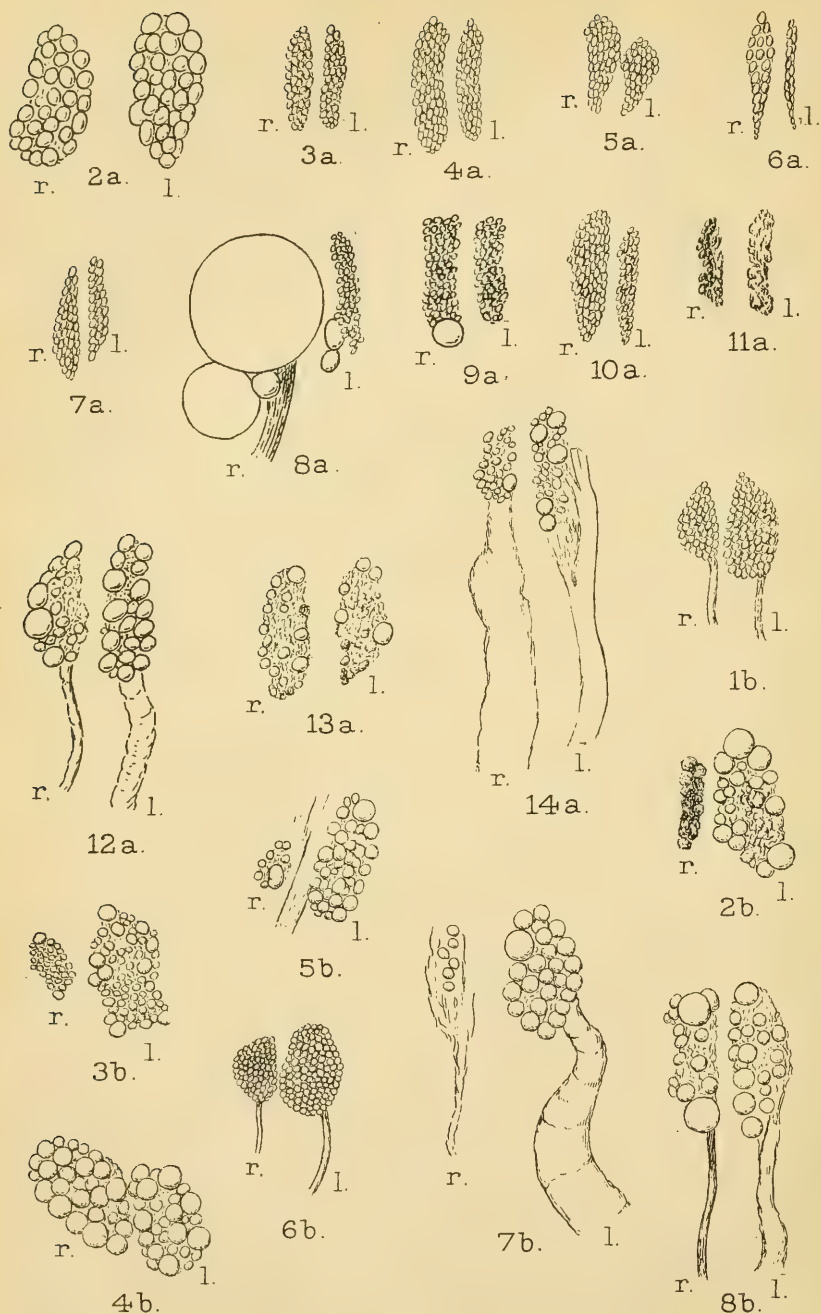
Fig. 1. Two weeks after commencement of moult.

Fig. 2. Moulded feathers from the wings.

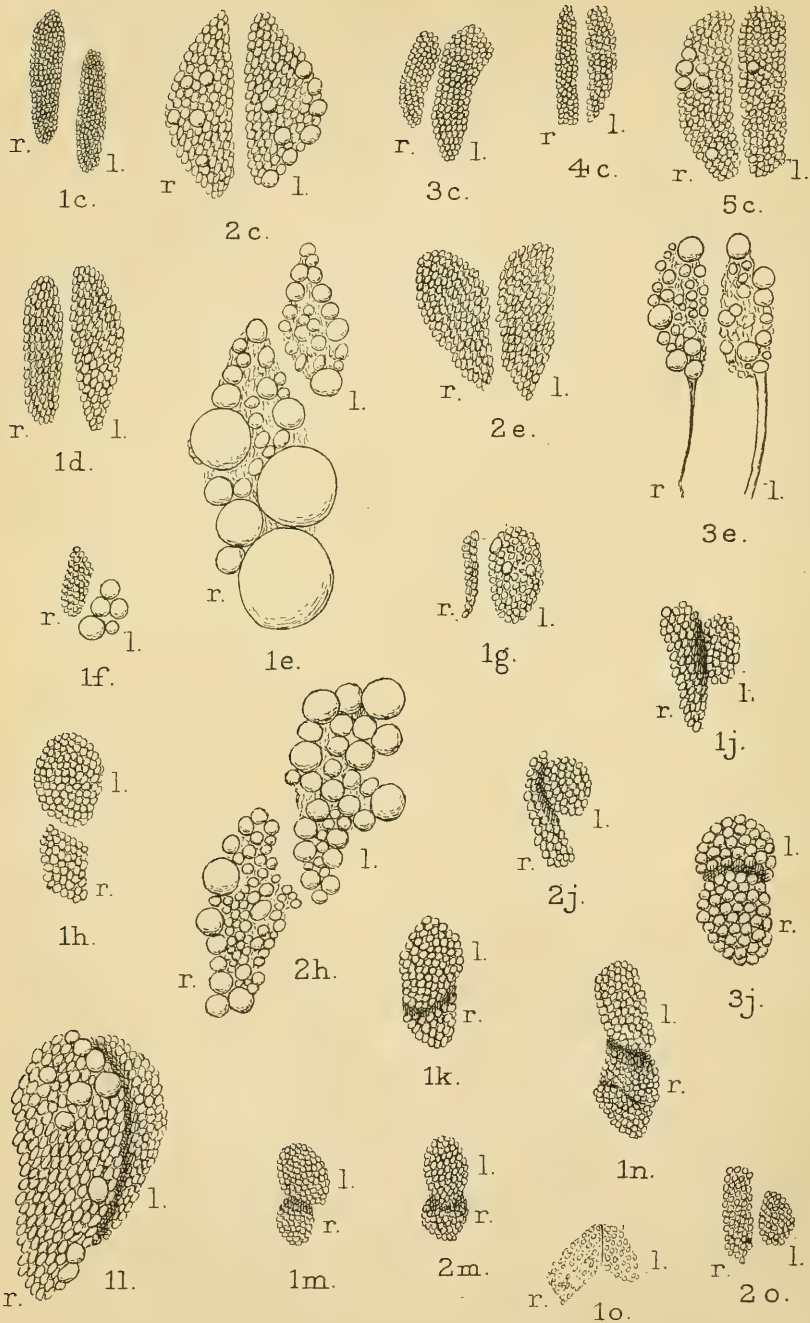
Fig. 3. Three weeks after commencement of moult. Scratching off the old plumage from the head.

Fig. 4. Same period as fig. 3.

Fig. 5. Moulded feathers of the King Penguin.



PAIRED OVARIES OF ACCIPITER NISUS (2a.-14a)
AND FALCO TINNUNCULUS (1b.- 8b.)

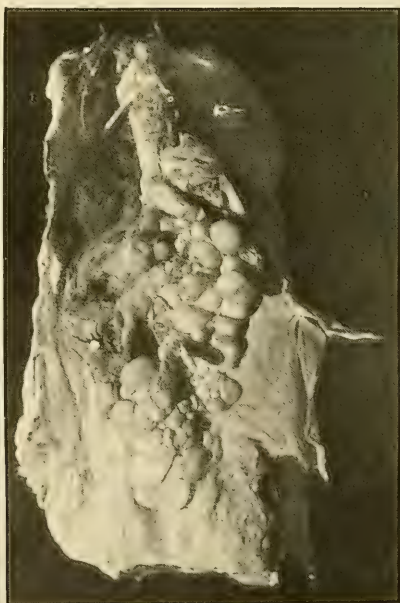




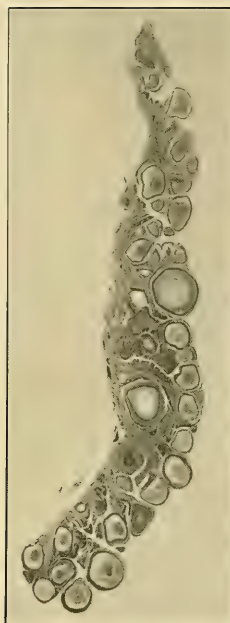
1.

3.

2.



OVARIES OF: 1. ACCIPITER NISUS 2. CIRCUS CYANEUS.
3. PODICIPES CRISTATUS.



1.



2.



3.



4.

6. On the Presence of two Ovaries in certain British Birds, more especially the Falconidæ. By T. E. GUNN, F.L.S.*

[Received October 23, 1911; Read November 7, 1911.]

(Plates II.-V.†)

In all vertebrated animals the reproductive organs or gonads are paired symmetrical glands lying to the inner side of the Wolfian body and in front of the kidney in the dorsal aspect of the body-cavity.

In the early stages of development these paired glands are found in every vertebrate from Fishes upwards. Morphologically indifferent at first, they become differentiated later on into the essential male (testis) or female (ovary) glands.

In exceptional cases a further change takes place leading to the suppression of one of the female gonads with its appendage, *e. g.*, certain Elasmobranch fishes, and—it is said—the whole class Aves. The suppression is supposed to be connected with the large size of the eggs developed by the individual, *e. g.*, *Scyllium* in fishes and *Uria* in birds.

In the embryo chick (of the fowl) the ridge of germinal epithelium is sufficiently differentiated by the fifth day to determine whether the primordial germ-cells of which it is largely composed are destined to furnish the individual with the permanent ova characteristic of the hen, or the spermatozoa of the cock bird: in other words, the ovaries are distinct from the testes at this date.

With regard to the male organs, their development pursues a normal course for the remainder of embryonic life, and the male chick steps out of the shell with two symmetrically placed and permanent functional testes.

With the female organs a further negative change takes place. The development of the ovary on the right side comes to a standstill and the organ atrophies, leaving little or no trace of its former presence. The oviduct dwindles with the ovary and is finally lost almost entirely; vestiges may be found more especially at the cloacal end of the tube, but it is never complete from end to end as a functional duct.

Exactly when this degeneration begins, and at what period of embryonic life the chick will be found with only the single left ovary, are apparently uncertain; but it is an accepted fact that the newly hatched female chick has but one ovary—that on the left side—and this one gland has to serve for the purposes of reproduction during the whole of her ovum-bearing existence.

Morphologists and ornithologists alike are agreed that adult female birds have but one functional ovary. Very few authors

* Communicated by F. MENTEITH OGILVIE, F.Z.S.

† For explanation of the Plates see p. 79.

make any reference even to remains of the right ovary being found on dissection, much less to a perfect functional organ, though they may allude to the persistence of portions of the Müllerian duct on that side.

Balfour* writes :—" In birds the left ovary alone is found in the adult, and is attached by the *mesovarium* to the dorsal wall of the abdominal cavity on the left side of the vertebral column."

Milnes Marshall† :—" In the embryo fowl there are two ovaries, but in the course of development the right ovary disappears and in the adult hen the left ovary is alone present. Of the two oviducts the right one is rudimentary ; the left one, which alone is functional, forms in the adult hen a wide convoluted tube."

And again‡ :—" In the female, or hen bird (of the fowl) the Müllerian duct of the right side, like the ovary, disappears, though traces of it may persist in the adult—the left Müllerian duct becomes the oviduct."

Wiedersheim § :—" In *Sauropsida*, as in other vertebrates, the form of the gonads is influenced by that of the body ; thus in Chelonians they are broad, while in the snake and snake-like lizards they are more elongated and, as well as in other lizards, are asymmetrical, the organ of one side lying more or less in front of that of the other.

" More room is thus obtained for the development of the ovaries, and in cases where the eggs are very large the organs of one side tend to disappear as in certain elasmobranchs. In birds, for instance, the left ovary only is completely developed and functional. . . .

" In birds the right oviduct as well as the right ovary becomes more or less completely degenerated."

Lillie || :—" The organs of reproduction of the hen are the ovary and oviduct of the left side of the body. Although the right ovary and oviduct are formed in the embryo at the same time as those on the left side, they degenerate more or less completely in the course of development so that only functionless rudiments remain.

" This would appear to be correlated with the large size of egg and the delicate nature of the shell, as there is not room for the eggs side by side in the lower part of the body-cavity."

Alex. Macalister ¶ :—" There are two fasciculate ovaria, of which

* 'Elements of Embryology,' p. 11. Foster and Balfour, 1883.

† 'Vertebrate Embryology,' pp. 228-229. Milnes Marshall, 1893.

‡ *Ibid.* p. 320.

§ 'Comparative Anatomy of Vertebrates,' p. 474. Wiedersheim (adapted by Prof. W. N. Parker, 1907).

|| 'Development of the Chick,' p. 21. Lillie, 1908.

¶ 'An Introduction to the Systematic Zoology and Morphology of Vertebrate Animals,' (organs of reproduction in Birds) pp. 159-160. Alex. Macalister, 1878.

only one (the left) is developed and functional. The right oviduct remains a hydatic; sometimes is developed anomalously, while the left atrophies; rarely the two remain. (Pigeons and Parrots)."

Bowdler Sharpe*:—"The right ovary of birds is always atrophied, and it is only in rare cases that rudiments of it are found (namely in the diurnal *Raptores*). The right oviduct is not so completely atrophied as is the ovary of the same side."

In the recently published 'Grouse in Health and Disease' Dr. E. A. Wilson writes (of that bird) †:—"There is but one ovary, and it lies always on the left side of the backbone of the bird. This development of the ovary, only on one side, is the reason for advising the examination to be made, as detailed above, on the left side always."

This last quotation is interesting in connection with the subject of paired ovaries, since over 2000 grouse passed through the hands of the Grouse Disease Committee and were carefully examined; of these nearly a quarter (476) were females, and not a single example of a persistent right ovary or its remains was found ‡. It is to be noted, however, that if the sexing were carried out, as Dr. Wilson recommended, by examination of the left side, persistent right ovaries might have been overlooked.

Newton §:—"In the female a pair of ovaries are developed, but with rare exceptions only that on the left side becomes functional. In young birds both oviducts are almost equally developed, but the right one soon becomes reduced to an insignificant ligamentous strand along the ventral side or part of the kidney.

"This one-sided suppression of the organs may possibly be referable to the inconvenience that might be caused were each oviduct to contain an egg ready to be deposited."

From the above quotations it will be seen that the majority of the writers do not admit the presence of a right ovary at all in the adult female. Sharpe speaks of *rudiments* || of the right ovary being retained in the diurnal *Raptores*, Newton very guardedly refers to "rare exceptions" where both ovaries are present, but he does not mention in what species of bird these exceptions were found. It is indeed rather doubtful if these instances came under his personal observation; had they done so he would probably have published the names of the species and

* Cassell's Natural History, vol. iii. p. 251. R. Bowdler Sharpe, 1883.

† 'Grouse in Health and Disease,' vol. i. p. 60.

‡ Out of 17 female grouse that have passed through my hands in the last four years, three have shown well-marked paired ovaries.—T. E. G.

§ 'Dictionary of Birds,' ("reproductive organs") p. 782. Alfred Newton, 1894.

|| Italics are mine (T. E. G.).

details of the parts as he found them. Rev. F. C. R. Jourdain* suggests that Newton's exceptions might have been drawn from a German source†.

Professor Taschenberg, the writer of the article referred to by Jourdain, says:—

“It happens not very rarely that *remains*‡ of the right ovary are retained, especially in the sparrow-hawk and buzzards, much more irregularly in other accipitres, and still more rarely in the owls.”

Ceteris paribus, a bird possessing two functional ovaries is clearly more fitted for the reproduction of its kind than the bird with only one. If disease or injury destroys the one ovary and spares the other, the bird can still fulfil the chief duty of its life, the bearing of ova. If the one ovary becomes exhausted (*e. g.* destruction of first nests) the other would act as a reserve to draw on in cases of necessity. If the fittest female is to survive in the long run, one would suppose that the bird that possessed the two complete genital tracts, the foundations of which were laid in the very early embryo, would surpass its fellow which had squandered fifty per cent. of its reproductive capital while still in the shell. That that is not the case we know.

Speaking in general terms, the rule holds good that adult females have but one ovary and one oviduct, those on the left side.

Why has the second ovary been abolished?

It has been suggested §, with some show of probability, that the suppression is in connection with the passage of the egg through the oviduct; that the danger involved by two eggs engaging simultaneously in the two oviducts would be very great, and would lead to fracture of the delicate shell, or rupture of the walls of the containing duct; to peritonitis, intestinal obstruction or some such calamity, and in any event death.

If such an accident—a fully-developed egg in the lower part of either oviduct at the same time—were to happen, no doubt the results would be untoward. A Guillemot with two full-sized eggs in its abdomen would presumably burst.

But is it necessary to suppose that such a sequence would follow the presence of two separate genital tracts?

I think not. The number of cases collected in this paper goes far to prove that death and disaster are neither the necessary nor even the common result of paired ovaries. It is contradicted by the frequency with which the Falconidæ are found with paired ovaries which are obviously functional. That a single ovary permits the bird to perpetuate its kind is true enough. The

* ‘British Birds,’ Dec. 1910, p. 218.

† ‘Naturgeschichte der Vögel Mitteleuropas,’ vol. i. p. 60, 1905. [Dr. Gadow, in Bronn’s ‘Thier-Reich, Vögel,’ p. 842, quotes from Stannius, and adds instances from his own observation of the persistence of the right ovary, particularly in diurnal birds of prey.—EDITOR P. Z. S.]

‡ Italics are mine (T. E. G.).

§ Newton, ‘Dictionary of Birds,’ p. 783.

excretion of urea can be carried on by one kidney if the other be destroyed by disease, or removed in its entirety by the surgeon; but the animal with one kidney only is admittedly less well off than the animal with the normal pair. The life would be called a bad one at any vertebrate life insurance office, and the premium charged would be correspondingly high. Two ovaries may not be a necessity, but they must be better than one. The suppression of the second ovary appears to be a retrograde step for which it is hard to find any adequate reason, and is almost without a parallel in vertebrate embryology.

In dissecting an immature female Sparrow-hawk (*Accipiter nisus*) (plumage of the first year) shot on the 9th of January, 1892, I found both ovaries equally developed, containing small eggs of uniform size.

In the following April a second example came under the notice of Mr. F. Menteith Ogilvie, who had happened to be with me when I skinned and examined the former specimen. He made the following note:—"April 11th, 1892. I dissected *A. nisus* ♀. Both ovaries well developed, eggs numerous and of various sizes—I think the forward condition of the ova shows the bird would have bred this season, though it was certainly only a last year's bird."

From 1892 up to the present date I have paid special attention to the sexual organs of all birds passing through my hands, in order to investigate the condition of the female generative system, the frequency with which the right ovary was found to persist, and the species in which such persistence occurred. In every case where paired ovaries were found I took notes and made as accurate sketches as I could with the specimen on the table before me. In 1895 and again in 1903 I recorded a number of these instances in two papers read at meetings of the Norwich Science Gossip Club*. Since then further examples have been added, bringing the total number of specimens with paired ovaries in my series to 45. These are grouped in bulk in Table I. (see p. 72), and are separately treated in detail in the Appendix.

Neither Table I. nor the Appendix includes several instances in which I have found the two ovaries in certain nestlings.

On July 7th, 1909, six nestling Sparrow-hawks with their parents (second year's plumage) were sent me from Suffolk (see Appendix 10^a). In sexing the nestlings I found that five were females and the sixth, a much smaller bird, a male. All the five female nestlings had paired ovaries, the glands averaging half an inch in length. They were equally developed and easy to recognise. The excessive proportion of females over males in the Sparrow-hawk in this instance is noteworthy—I have observed the same fact on a former occasion†, in which, out of six nestlings, four were females and two were males.

* Report of Proceedings, May 1895; May 1903.

† 'Zoologist,' 1885, p. 51.

Exceptions to the rule that breeding females possess but a single left ovary must be very considerable. Since especially looking for paired ovaries I have found them comparatively common—the natural inference is that for many years I had overlooked them.

The number of examples of paired ovaries, apparently functional and ready for ovulation in this series, negatives the idea of the danger to life necessarily involved by the possession of a paired generative system. If death were the common result of a right and left ovary (with the corresponding ducts) it would seem likely that specimens would have come to hand before now demonstrating the pathology of the fatality and its mode of occurrence. I have never handled such a bird in the flesh, nor seen any reference in print to dissections illustrating death from this cause.

Is it not a reasonable conception that the nervous system would govern the activity of the ovaries—and of course the oviducts—during the period of turgescence associated with the breeding season, utilizing the left ovary only, or the right ovary only for the egg-supply and the other for a reserve—or in cases of necessity utilizing both ovaries?

(a) In most of the later examples of paired ovaries in a state of activity in my series—birds that were obtained in June and early July and had then laid their full complement of eggs for the season—all the evidence goes to show that though two ovaries were present only one has been utilized for the production of eggs (*cf.* 1^c: 8^a); the other ovary developing eggs up to a point—the eggs then ceasing to grow in size and finally shrinking with those in the working ovary to the small undeveloped ova common to birds in the non-breeding season.

In some of the earlier examples—birds obtained between March and early May (*cf.* 5^c; 1^d; 2^a; 2ⁿ)—both ovaries are well and equally developed with eggs of approximately equal size in either ovary—so that at this time it is impossible to guess which ovary is to furnish the season's eggs, or whether the supply is to be drawn from both.

This seems to point to the nervous system determining which ovary shall be finally selected for the year's output.

Both ovaries are developed up to a certain point; and then one comes to a standstill, while the requisite number of eggs in the other continue to increase in size until they are ripe for the oviduct. After they are shed both ovaries rapidly undergo the normal process of involution and become comparatively insignificant.

According to this theory the regulating nervous stimulus could be switched off one ovary and on to the other as best suited the requirements of the organism.

(b) If both ovaries are to share in the production of one clutch of eggs, then one can imagine each oviduct in turn being inhibited, while an egg is engaged in the duct of the opposite side, much as

a signaller refuses to accept a new train until his section is cleared of the old one.

(c) Finally there remains the question whether *one* oviduct can serve *two* ovaries. There is not much evidence for or against this supposition.

In some cases the appearance of the paired ovaries rather suggests that *both* had taken part in discharging ripe ova, while only *one* oviduct shows much development.

On the other hand, the normal involution of the oviduct is so extraordinarily rapid, that in some specimens with well-developed ovaries, which are known to have passed the last eggs of their clutch quite recently (3^e), the oviducts on both sides are merely represented by ill-defined strands quite difficult to differentiate macroscopically from the surrounding tissues, and but little more marked than the oviduct (or ducts) would be in the autumn and winter months.

The upper portion of the oviduct is provided with a mesentery which is sufficiently long to allow a very considerable amount of free play. There seems no physical objection to the open end of the tube (*ostium abdominale*) swinging across the mid-line of the spine *, and grasping the ripe ovum of the opposite ovary with nearly the same facility as the ovum of its own side.

Extra-tubal gestation, by which I mean the shedding of a ripe ovum into the peritoneal cavity, is, so far as we know, an exceedingly rare accident among birds. Dr. Wilson † mentions such a case.

Two functional ovaries and one duct collecting eggs from both sides would be exactly the conditions which would predispose to such an occurrence.

Returning to the paired ovaries, it is manifest that these cases are not exceedingly rare among many quite widely separated groups of British birds. In one family, the Falconidæ, such instances may be termed positively common. One cannot help realising that if 45 examples come under the notice of one man in the course of nineteen years, double ovaries must be something more than of occasional occurrence.

The obvious conclusion seems to be that they are not found because they are not looked for.

In the writings of English ornithologists I can find but one specific record (and that a very recent one) of paired ovaries.

Dr. C. B. Ticehurst ‡ describes three cases in which he found the right ovary persisting—all three examples were Sparrow-hawks.

* Except in the Falconidæ the examples of paired ovaries generally show an asymmetrical state of affairs, with the right ovary below the left, and at the same time carried over somewhat laterally from right to left. In such cases as these the left oviduct would have no further to go for the eggs from the right ovary than for those from the left.

† 'Grouse in Health and Disease,' p. 183.

‡ 'British Birds,' November 1910, p. 188.

Some very excellent notes on the subject by Signora C. Picchi appear in the July (1911) number of 'British Birds,' pp. 45-49.

This lady gives 27 examples of a persistent right ovary, the large majority of them (25 out of 27) are found among the Falconidæ, especially the genera *Falco* and *Circus*.

For the purposes of this paper I have reduced Signora C. Picchi's notes to a tabulated form (Table II., p. 73) in order to render it readily comparable with the table (Table I.) constructed from my own series.

Ornithologists expect to find either two testes or one ovary. The intestines and peritoneal folds are raised and gently turned over from the (bird's) left to right, which of course exposes the left half of the dorsal wall of the body-cavity. In the case of the female the left ovary is satisfactorily identified, and there the dissection usually stops.

The conditions obtaining on the right side of the body-cavity are not investigated at all,—a second ovary may or may not be present, but by this method of examination it is effectually hidden by the pile of intestines pushed over from the left side.

The percentage of double ovaries found in this paper in certain genera in the family (*Circus* 9 out of 12, *Accipiter* 14 out of 20) is so large that one is forced to the conclusion that individuals of the same genera dying in captivity would also furnish a considerable percentage of paired ovaries.

In the 45 instances of double ovaries referred to (Table I., group 1) nearly three quarters (33 out of 45) are of one family, the Falconidæ.

In Signora C. Picchi's notes (Table II., group 1) 27 examples are given, and of these 25 are drawn from the same source.

The remaining twelve examples in my series (Table I., group 2) represent seven species that, with the exception of the two Grouse, are widely separated. The seven species in fact belong to six different orders.

The remaining two in Signora C. Picchi's notes (Table I., group 2) also occur in two very diverse species, one of them being an Owl (*Striges*) and the other a Rook (*Corvus*).

Oddly enough, I have no note of paired ovaries among the Strigidæ; but that may be due to so few of these birds passing through my hands in recent years, owing to the wise protection which is now almost universally afforded owls in this country.

Table I. (T. E. G.) and Table II. (C. Picchi) show clearly enough that the right ovary *does* persist in not a few cases; that it is sometimes developed equally with the left and sometimes very considerably exceeds that gland.

1^e (*Circus cineraceus*), in which the right ovary has several large ripe ova whereas those of the left are small.

8^a (*Accipiter nisus*). The right ovary is but fragmentary, and shows only three ova: one as large as an ordinary sized marble, another about one third that size, and the third about as large as a hempseed. Those of the left were quite small. The right ovary had evidently been the source from which the season's eggs

had been derived, and had become nearly exhausted: the left ovary, on the other hand, showed little more activity than the quiescent gland of the autumn months.

7^b (*Falco tinnunculus*). The left ovary contained a cluster of eggs of even size with one slightly larger—the left oviduct well developed. The right ovary contained but six very small eggs, and the oviduct was represented by only a narrow ligamentous strand.

14^a (*Accipiter nisus*). Both ovaries were present, the right half the size of the left, and contained small eggs only.

Of the oviducts the right was double the width of the left and had the appearance of having recently passed eggs.

12^a (*Accipiter nisus*). Both ovaries and their corresponding ducts present, the left oviduct being the wider.

This female had probably quite recently passed her full clutch of six eggs, which were taken from the nest by the keeper at the same time that he killed the parent bird. The remaining eggs in both ovaries were all small. The left oviduct had quickly become reduced in width after passing the last of the six eggs, which event must have taken place not more than two days before.

From the greater width of the left oviduct in 7^b, of the right in 14^a, of the left in 12^a, we may reasonably infer that they had severally been the latest oviducts in active service.

This indicates that either the right or the left oviduct may be the functional one—and that one or other may work as the maturity of the ova in each respective ovary requires their service.

In conclusion I would again draw attention to Tables I. and II.

In Table I., to take two extreme instances, out of six female Hen Harriers (*Circus cyaneus*) examined five had a persistent right ovary: out of fifty female Woodcock (*Scolopax rusticula*) examined only one retained the gland on the right side.

If the figures in the two tables are combined we get the following results:—

Grand total, 72 examples of paired ovaries out of 212 females examined, made up of two sub-divisions A and B.

A. Falconidæ	56 out of 98.
B. Species from any family other than the Falconidæ	14 out of 112.

This shows in rather a startling manner the frequency with which paired ovaries are found in the Falconidæ (or rather in the genera which have come under examination) as compared with any other family of British birds.

There is a second point of some interest in regard to the anatomical position of the ovaries. In the Falconidæ these are symmetrically placed and are arranged, almost without exception, parallel to each other, and on about the same level, lying on the kidney of the same side and separated from each other by the vertebral column.

TABLE I.

Compiled from T. E. Gunn's notes: enumerating the species examined and the proportion the double ovaries occurred. Specimens obtained in Great Britain.

		Sparrow-Hawk	14 out of 20 ♀ examined.
A. Falconidæ (7 species) 33 out of 50 ♀ examined =66%.	<i>Falco</i> 10 18 =66%	.....	.....
		(<i>Falco tinnunculus</i>)	8 " 12 "
		(<i>F. subbuten</i>)	1 " 2 "
		(<i>F. peregrinus</i>)	1 " 4 "
	<i>Circus</i> 9 12 =75%	.....	.....
		(<i>Circus cyaneus</i>)	5 " 6 "
		(<i>C. cinereus</i>)	3 " 4 "
		(<i>C. æurginosus</i>)	1 " 2 "
	Great Crested Grebe.....	(<i>Podiceps cristatus</i>)	2 " 4 "
		(<i>Lagopus scoticus</i>)	3 " 17 "
B. Families other than Falconidæ (7 species) 12 out of 101 ♀ examined =11.88%.	Red Grouse	(<i>Tetrao tetrix</i>)	1 " 5 "
		(<i>Cygnus bewicki</i>)	1 " 4 "
		(<i>Rallus aquaticus</i>)	2 " 7 "
		(<i>Scelopar rusticula</i>)	1 " 50 "
	Black Grouse	(<i>Larus minutus</i>)	2 " 14 "
	
	Bewick's Swan .....	.....	.....
	
	Water Rail .....	.....	.....
	

In examples of paired ovaries found in birds other than the Falconidæ, the arrangement of the ovaries is more irregular and uncertain. They are seldom symmetrically placed, the general tendency being for the right ovary to move downwards and to the left, so that the whole of the left ovary and the greater part of the right are contained in the left half of the body-cavity, one ovary more or less overlapping the other.

It would appear possible that the partial migration of the right ovary to the left side and below the left ovary may be of importance as furnishing more space for the development of the ovaries. It probably does mark a milestone on the road leading to its final disappearance.

TABLE II.

Compiled from Signora Cecilia Picchi's notes published in 'British Birds,' July 1911, Vol. V. No. 2, pp. 45-59. Specimens obtained in Italy with the exception of two from Sardinia.

		Sparrow-Hawk	(<i>Accipiter nisus</i>)	3 out of 7 ♀ examined.
A. Falconidæ (11 species) 23 out of 48 ♀ examined =48°/o (47·91).	<i>Falco</i> 9 18 =50°/o	Kestrel	(<i>Falco tinnunculus</i>)	2 " " "
		Lesser Kestrel *	(<i>F. cenchris</i>)	1 " " ? "
		Merlin	(<i>F. aesalon</i>)	2 " " 4 " "
		Red-footed Falcon ..	(<i>F. vespertinus</i>)	5 " " 8 " "
		Hobby *	(<i>F. sublatco</i>)	1 " " ? " "
	<i>Circus</i> 7 11 =50°/o	Hen Harrier	(<i>Circus cyaneus</i>)	1 " " 4 " "
		Marsh Harrier	(<i>C. æruginosus</i>)	4 " " 6 " "
		Pallid Harrier	(<i>C. macrurus</i>)	2 " " 4 " "
		Common Buzzard	(<i>Buteo vulgaris</i>)	3 " " 6 " "
		Serpent Eagle	(<i>Circæetus galliens</i>)	1 " " 3 " "
B. Families other than Falconidæ (2 species) 2 out of 11 =18°/o	{	Short-eared Owl	(<i>Asio accipitrinus</i>)	1 " " 5 " "
		Rook	(<i>Corvus frugilegus</i>)	1 " " 6 " "

* Not included in the figures, as the number of females examined is not known.

I have to express my thanks to Mr. F. Menteith Ogilvie, who has taken a great interest in the subject from the first, and has given me much advice and assistance in the construction of the paper. I am further indebted to him for obtaining the stereoscopic photographs * of some of the later specimens, microscopical sections of the paired ovaries 5° and 2°, and photographs of these same sections under low and medium magnifications.

* The stereoscopic photographs were taken by Mr. W. Chesterman, of the Department of Human Anatomy; Plates II. and III. were executed from Mr. Gunn's original drawings by Mr. C. J. Bayzand, of the Department of Geology, University of Oxford.—(F. M. O.)

APPENDIX.

SPARROW-HAWK (*Accipiter nisus*). $\frac{14}{20}$.†(Pl. II. figs. 2^a-14^a; Pl. IV. fig. 1.)

1^a. Date, January 9th, 1892. Locality, Suffolk. Age 8 to 9 months. Both ovaries present, each containing small eggs.

2^a. May 21st, 1894. Suffolk. In second year's plumage. Paired ovaries of equal size, being filled with uniform eggs.

3^a. November 8th, 1900. Norfolk. In second year's plumage, showing both ovaries: eggs small, and uniform in size.

4^a. December 20th, 1906. Derbyshire. Two years of age. Right and left ovaries nearly equal in size. Right a trifle the larger, both filled with cream-coloured eggs.

5^a. February 1st, 1907. Suffolk. Entering its second year. Both ovaries present, the right being larger, and the ova uniform in size.

6^a. October 3rd, 1908. Suffolk. In its first year's plumage. Two small thin ovaries present. Right larger than left. Eggs very small.

7^a. October 7th, 1908. Norfolk. First year's plumage. Two ovaries present, right trifle the larger. Eggs small.

8^a. May 7th, 1909. Suffolk. In its second year's plumage. Two ovaries with eggs, the right having three eggs, one as large as an ordinary marble, the second about one third its size, and the third about the size of a hempseed. The left ovary contained two as large as hempseed, the remainder very small.

9^a. * June 9th, 1909. Suffolk. Two years old. Two ovaries present, the right being larger and containing one large egg, the remainder very small and presenting three different colours, pale yellow, cream, and black.

10^a. July 7th, 1909. Suffolk. In second year's plumage. Two ovaries present, the right as large again as the left, both containing small cream-coloured eggs. The full clutch of six nestlings was sent with the parent birds. Of these five were females and one a male; all five females had well-defined paired ovaries.

11^a. May 26th, 1911. Suffolk. Two ovaries, apparently exhausted, and too decomposed to preserve.

12^a. * May 26th, 1911. Norfolk. Not less than three years old. Both ovaries nearly equally developed. The left oviduct much wider than the right. This bird had laid its full complement of six eggs; quite fresh when taken by the keeper.

* Preserved as a museum specimen.

† In the fractions at the head of each species the numerator indicates the number of examples of paired ovaries found, and the denominator the total number examined,

$\frac{14}{20}$ is interpreted 20 females of *A. nisus* examined and 14 found with paired ovaries.

13^a. † May 27th, 1911. Norfolk. Age two years. Two ovaries present and equally developed. I examined this bird the day after death; it had been exposed to the sun, so was somewhat decomposed, but I was able to preserve the ovaries. Its six fresh eggs were also taken by the keeper.

14^a. ‡ June 8th, 1911. Suffolk. Second year. Both ovaries present. The left containing small and larger eggs. The right with small eggs only. The two oviducts well developed, that of the right being twice the width of the left. The ostium abdominale of the left duct is well shown in this specimen.

KESTREL (*Falco tinnunculus*). $\frac{8}{12}$.

(Pl. II. figs. 1^b–8^b.)

1^b. January 15th, 1901. Norfolk. Adult. Two ovaries present, but not equal in size, the right ovary being about half as large as the left, but the oviduct was more prominent in the right.

2^b. * June 7th, 1909. Suffolk. Adult plumage. Two ovaries present, the right small, the left quite four times as large as the right. Eggs of two sizes, the larger of a pale cream, a few of the smaller that were scattered were of a rich yellow colour.

3^b. * June 7th, 1909. Suffolk. Adult. Two ovaries, the right a small dark gelatinous mass with small eggs; the left about six times as large and contained eggs of various sizes of a yellow colour, a dark gelatinous mass being in the centre.

4^b. May 24th, 1910. Norfolk. Adult plumage. Two ovaries about equal in size, the eggs in the right ovary somewhat the larger.

5^b. May 25th, 1910. Suffolk. Second year's plumage. Two ovaries present. The right in a fragmentary state but containing a few eggs of two sizes. The left ovary was about six times larger, with eggs of various sizes, none large.

6^b. § January 6th, 1911. Norfolk. Second year. Both ovaries present. The left as large again as the right. Eggs small and of uniform size. Both oviducts thin; the left very attenuated.

7^b. * May 10th, 1911. Suffolk. Two years old. Left ovary full of eggs of uniform size, with the exception of a single larger one. Left oviduct exceedingly well developed, right ovary small and fragmentary; six small eggs only; right oviduct a fine ligamentous strand.

8^b. * May 26th, 1911. Suffolk. Age two years. Both ovaries present. The left larger and full of eggs, the right ovary smaller with fewer eggs, two of which were, however, larger than those in

* Preserved as a museum specimen.

† Stereoscopic photograph of the ovaries *in situ*.

‡ Sections of the right and left ovaries; photographs of the same.

§ Stereoscopic photograph of the ovaries *in situ*.

the left. Both oviducts represented by thin strands only, the left being more evident.

HEN HARRIER (*Circus cyaneus*). $\frac{5}{6}$.

(Pl. III. figs. 1^c–5^c; Pl. IV. fig. 2; Pl. V. figs. 1–4.)

1^c. November 4th, 1893. Norfolk. Second year. Both ovaries present; eggs of a rich cream colour, small and of uniform size.

2^c. April 9th, 1900. Suffolk. Probably three years old. This bird possessed two ovaries which contained eggs of two sizes.

3^c. January 10th, 1908. Norfolk. In second year's plumage. Both ovaries present, the left one as large again as the right. Both filled with small eggs of uniform size.

4^c. January 7th, 1907. Suffolk. In its second year. Two ovaries present; the left slightly the larger. Full of small eggs.

5^c. *† March 30th, 1911. Norfolk. Age two years. Both ovaries equal, containing cream-coloured eggs of two sizes; the majority small, the right ovary having more larger-sized eggs than the left. The two ovaries were packed closer together than any I had hitherto seen.

MARSH HARRIER (*Circus aeruginosus*). $\frac{1}{2}$.

(Pl. III. fig. 1^d.)

1^d. April 17th, 1907. Derbyshire. Two years old. Both ovaries present, the left a trifle the larger; both full of small eggs of uniform size.

MONTAGU'S HARRIER (*Circus cineraceus*). $\frac{3}{4}$.

(Pl. III. figs. 1^e–3^e.)

1^e. May 15th, 1903. Suffolk. Adult, three to four years old. Both ovaries present, the right containing much larger eggs of varying sizes, the largest just half an inch in diameter, and most of them of a bright orange colour. The left ovary contained small eggs of a yellowish cream colour.

2^e. July 3rd, 1909. Suffolk. Two years old. The two ovaries present. Eggs very small, uniform in size, and of two shades of colour—pale and deep yellow.

3^e. ‡ June 17th, 1911. Suffolk. Adult, probably three years. Two ovaries equal; containing a mass of eggs of various sizes and

* Sections of the right and left ovaries; photographs of the same.

† Stereoscopic photograph of the ovaries *in situ*.

‡ Sections of the right and left ovaries; photographs of the same.

of pale yellow and flesh colour; the left oviduct a fine strand only, that of the right very fine and thin.

HOBBY (*Falco subbuteo*). $\frac{1}{2}$.

(Pl. III. fig. 1^f.)

1^f. June 6th, 1907. Suffolk. Two years old. Two ovaries present; the left contained five large eggs, and the right some very small ones.

PEREGRINE FALCON (*Falco peregrinus*). $\frac{1}{1}$.

(Pl. III. fig. 1^g.)

1^g. November 22nd, 1907. Suffolk. Three years old. Two ovaries present, the right small and thin, with small eggs; the left was quite four times larger and had some eggs of two sizes.

GREAT CRESTED GREBE (*Podiceps cristatus*). $\frac{2}{4}$.

(Pl. III. figs. 1^h, 2^h; Pl. IV. fig. 3.)

1^h. * November 26th, 1910. Suffolk. Two ovaries, the right below the left and overlapped by it; both filled with small eggs. The upper (left) ovary the larger.

2^h. † February 28th, 1911. Norfolk. Probably three years old. Two ovaries present, the left slightly larger than the right; eggs of various sizes and of a yellow colour. The right ovary below the left and slightly overlapped by it.

RED GROUSE (*Lagopus scoticus*). $\frac{3}{17}$.

(Pl. III. figs. 1j–3j.)

1j. October 26th, 1907. Argyllshire. Two ovaries, situated side by side, the right double the length of the left. Both filled with small eggs of uniform size.

2j. October 26th, 1907. Argyllshire. Two ovaries; same remarks as above.

3j. November 29th, 1910. Argyllshire. Two ovaries of equal size and rounded form. The left ovary is superior and is overlapped by the right ovary, which lies nearly directly below it.

BLACK GROUSE (*Tetrao tetrix*). $\frac{1}{3}$.

(Pl. III. fig. 1^k.)

1^k. August 30th, 1907. Staffordshire. Probably three years old.

* Stereoscopic photograph of the ovaries *in situ*.

† Preserved as a museum specimen.

This bird had partly assumed the plumage of the male with its black breast and forked tail, the rest of the plumage being a mixture of black cock and grey hen.

Two ovaries present and equally developed, the left slightly overlapping the upper part of the right ovary; both contained eggs of uniform size.

BEWICK'S SWAN (*Cygnus bewicki*). $\frac{1}{4}$.

(Pl. III. fig. 1^l.)

1^l. January 5th, 1900. Scotland. Adult. It possessed two ovaries; one placed in front and nearly covering the other. The front and larger one was undoubtedly the right ovary and contained eggs of various sizes; the left was smaller, containing eggs of uniform size.

WATER RAIL (*Rallus aquaticus*). $\frac{2}{7}$.

(Pl. III. figs. 1^m, 2^m.)

1^m. *† December 27th, 1907. Suffolk. Both ovaries present, the left slightly the larger, and above the right, which it overlaps at the upper part. Each ovary is filled with small eggs of uniform size.

2^m. December 26th, 1910. Norfolk. Two ovaries equally developed, and as in previous instance, one is situated immediately above the other, eggs being uniform in both.

WOODCOCK (*Scolopax rusticula*). $\frac{1}{50}$.

(Pl. III. fig. 1ⁿ.)

1ⁿ. December 9th, 1909. Argyllshire. Two ovaries present, and situated one above the other, the left overlapping the upper part of the right. This latter ovary is slightly the larger and seemed partially twisted at its extremity; both full of small uniform eggs.

LITTLE GULL (*Larus minutus*). $\frac{2}{14}$.

(Pl. III. figs. 1^o, 2^o.)

1^o. February 5th, 1902. Suffolk. Bird in immature plumage, *i. e.* first year. The right and left ovaries are present, and meet in an apex above with a small blood-vessel overlying the junction. Both ovaries filled with small eggs.

2^o. January 6th, 1906. Suffolk. Adult. Both ovaries present, and arranged side by side; the right is twice the length and size of the left, and both are full of small cream-coloured eggs of uniform size.

* Stereoscopic photograph of the ovaries *in situ*.

† Preserved as a museum specimen.

EXPLANATION OF THE PLATES.

For further details see Appendix (p. 74).

PLATE II.

Paired Ovaries.

- Figs. 2^a-14^a. Sparrow-Hawk (*Accipiter nisus*).
 1^b-8^b. Kestrel (*Falco tinnunculus*).
 (r., right ovary. l., left ovary.)

PLATE III.

Paired Ovaries.

- Figs. 1^c-5^c. Hen Harrier (*Circus cyaneus*).
 1^d. Marsh Harrier (*C. æruginosus*).
 1^e-3^e. Montagu's Harrier (*C. cineraceus*).
 1^f. Hobby (*Falco subbuteo*).
 1^g. Peregrine Falcon (*Falco peregrinus*).
 1^h, 2^h. Great Crested Grebe (*Podiceps cristatus*).
 1ⁱ-3ⁱ. Red Grouse (*Lagopus scoticus*).
 1^k. Black Grouse (*Tetrao tetrix*).
 1^l. Bewick's Swan (*Cygnus bewicki*).
 1^m, 2^m. Water Rail (*Rallus aquaticus*).
 1ⁿ. Woodcock (*Scolopax rusticula*).
 1^o, 2^o. Little Gull (*Larus minutus*).
 (r., right ovary. l., left ovary.)

PLATE IV.

Paired Ovaries.

- Fig. 1. Sparrow-Hawk (*Accipiter nisus*) $\times 1\frac{1}{2}$. Both ovaries present, the right nearly exhausted and containing small eggs only. Both oviducts well developed; the right three or four times the size of the left and apparently the last in use; the left oviduct is well defined, the ovarian end of the duct is turned directly downwards and to the left, and the *Ostium abdominale* is clearly seen. (Appendix 14^a.)
 2. Hen Harrier (*Circus cyaneus*) $\times 1\frac{3}{4}$. Symmetrical paired ovaries equally developed and containing eggs of approximately the same size. (Appendix 5^a.)
 3. Great Crested Grebe (*Podiceps cristatus*) $\times 1\frac{1}{2}$. Asymmetrical paired ovaries. The right ovary lies below the left, and is mostly in the left half of the body-cavity. (Appendix 2^h.)

PLATE V.

Microscopic sections of the ovaries of the Hen Harrier (*Circus cyaneus*).
 (Appendix 5^c.)

- Fig. 1. Left ovary $\times 4\frac{1}{2}$ showing general ovarian structure.
 2. A selected ovum from fig. 1 showing germinal spot, protoplasm, germinal epithelium, and vascular connective tissue capsule ($\times 69$).
 3. Right ovary $\times 5$.
 4. A selected ovum from fig. 3 $\times 50$.

7. On some Collembola from India, Burma, and Ceylon; with a Catalogue of the Oriental Species of the Order. By A. D. IMMS, D.Sc., B.A., Forest Zoologist to the Government of India; late Professor of Biology, Muir College, and Fellow of the University of Allahabad*.

[Received May 29, 1911: Read November 7, 1911.]

(Plates VI.-XII. and Text-figures 14 & 15.)

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III. A Catalogue of the Oriental Collembola	118
IV. A Summary of General Conclusions	121
V. Explanation of the Plates	122

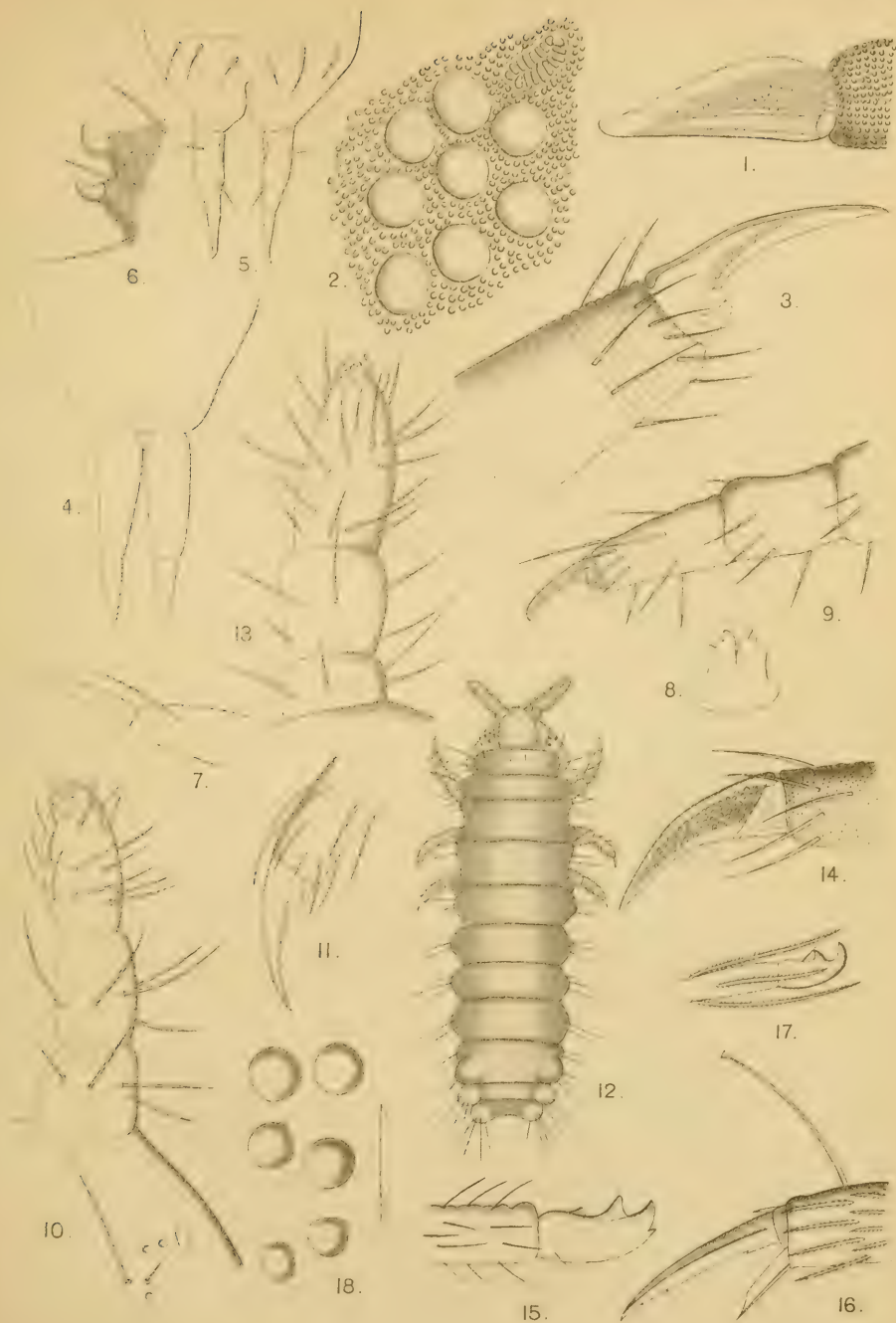
I. INTRODUCTORY REMARKS.

During the last decade the Collembola have attracted a considerable amount of attention both from morphologists and systematists. Collections of these primitive insects have been studied from various regions of the world. Hitherto, however, I am not aware that any species of the Order have been known and recorded from the Indian Empire. The present paper is intended as a small contribution towards a knowledge of the Collembola of that extensive region.

I am indebted to Dr. N. Annandale for handing over to me for examination the specimens contained in the collections of the Indian Museum, and to Mr. E. E. Green for forwarding me two species from Ceylon. In addition to the species received from the above two sources, I have myself collected a number of examples in several parts of India, from Allahabad in the "plains" up to an altitude exceeding 12,000 feet in the Himalayas. The area thus worked over lies within two zoo-geographical regions. The collecting, however, has only been done during casual intervals, and generally when I was occupied in searching for other forms of animal life. I wish to acknowledge the facilities for consulting entomological literature that were afforded me by the libraries attached to the Indian Museum, Calcutta, and the Agricultural Research Institute, Pusa.

Altogether 571 specimens of Collembola have been examined and from among these, 4 genera and 27 species are described as new, and 3 species were already known.

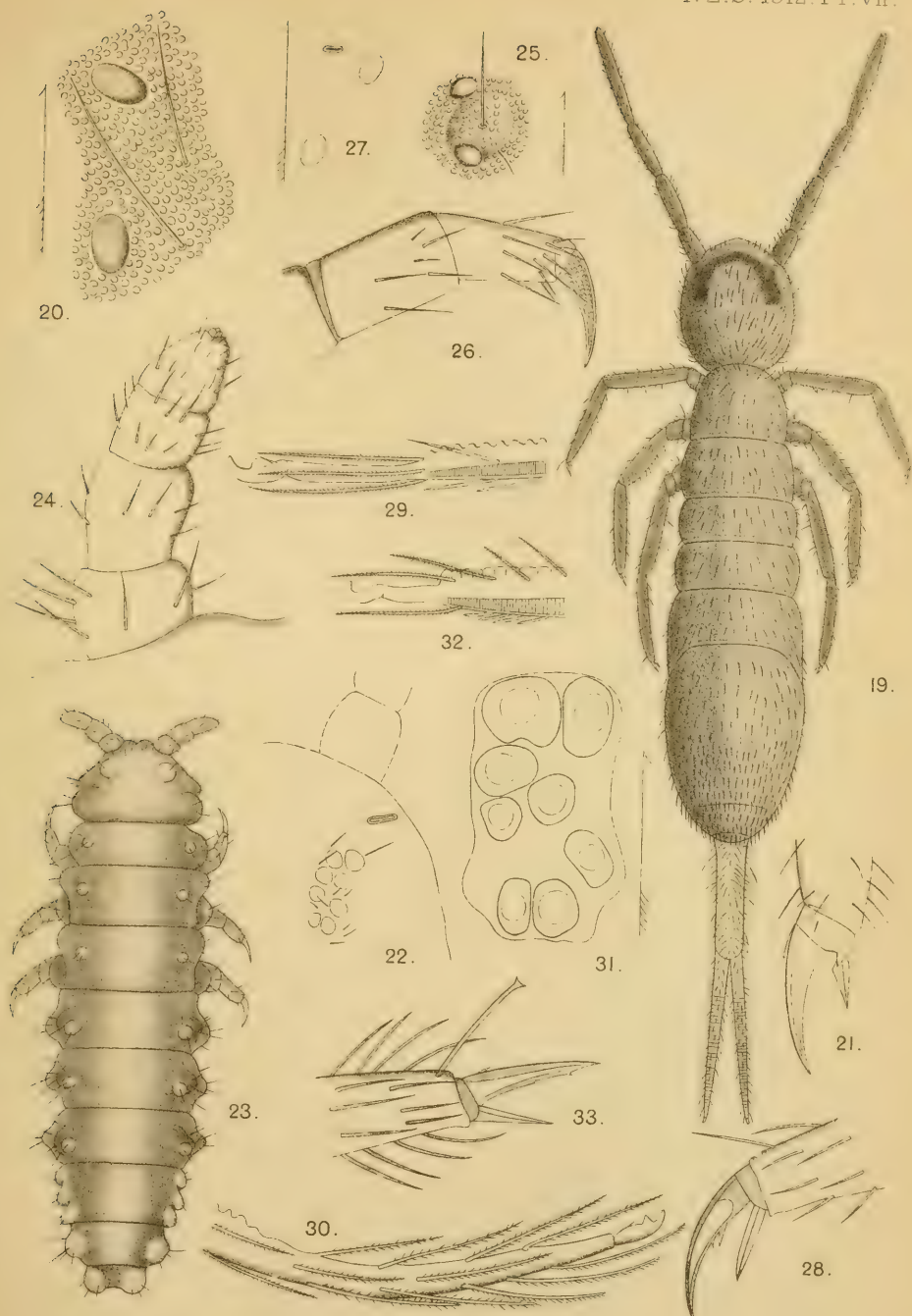
* Communicated by A. E. SHIPLEY, M.A., F.R.S., F.Z.S.



A.D. Imms ad nat. del.

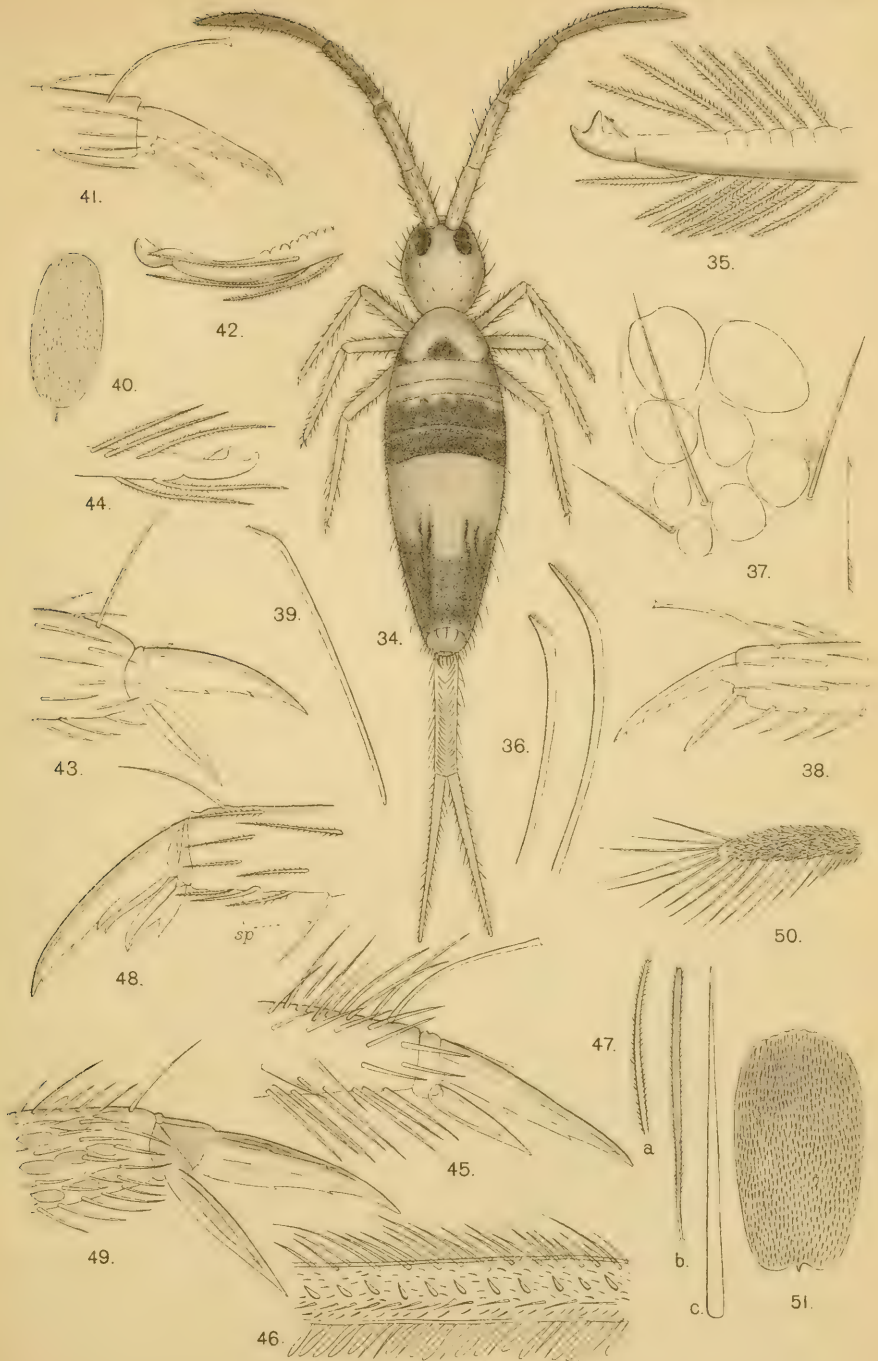
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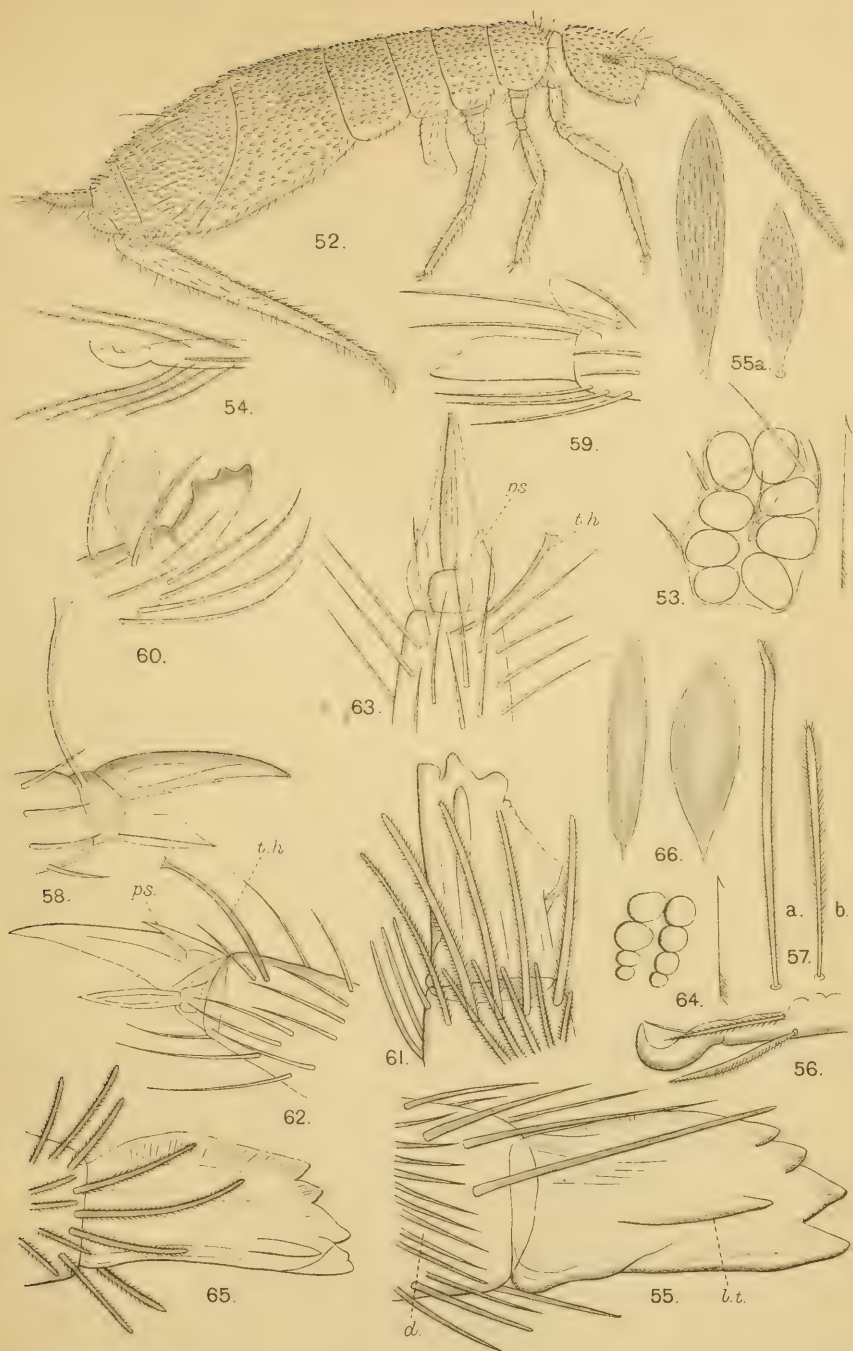
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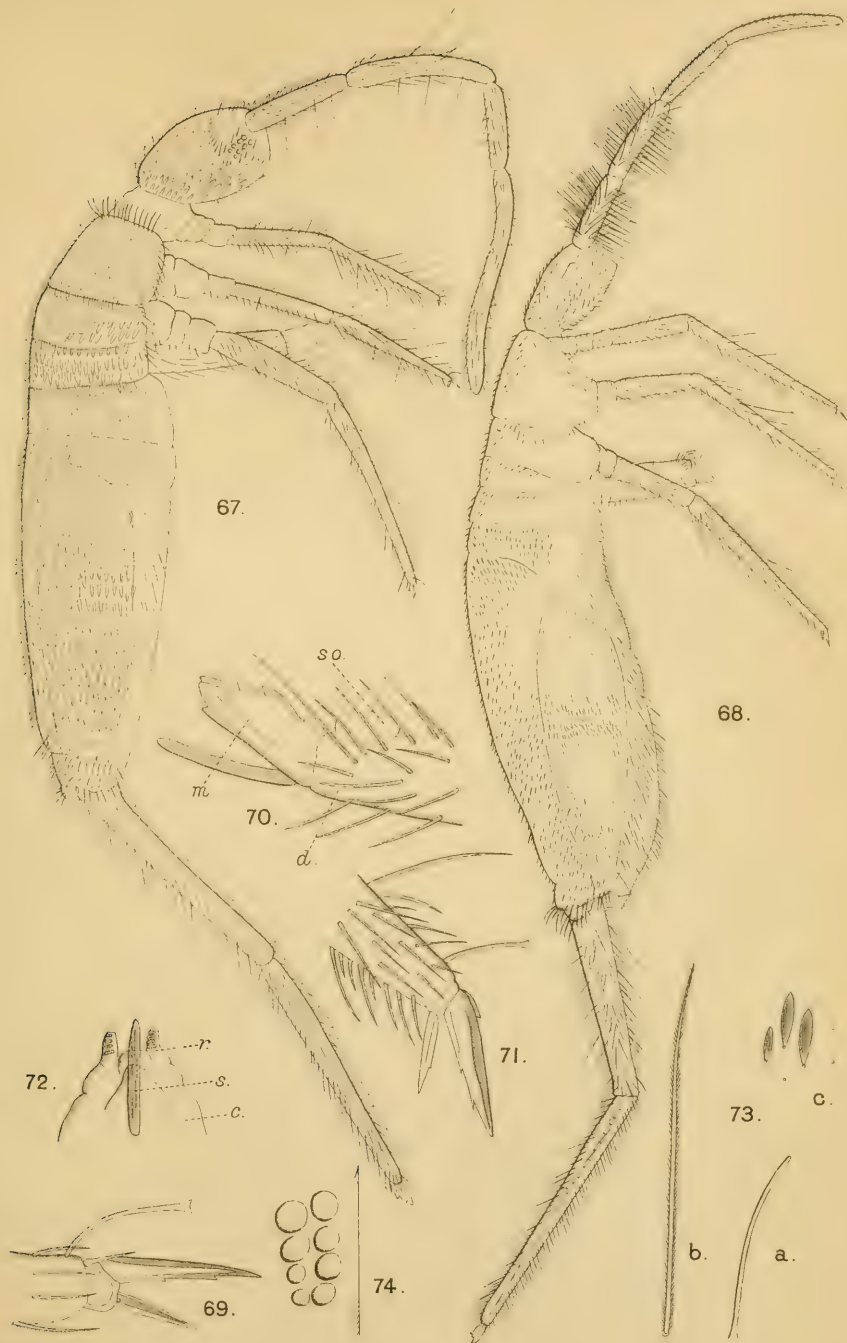




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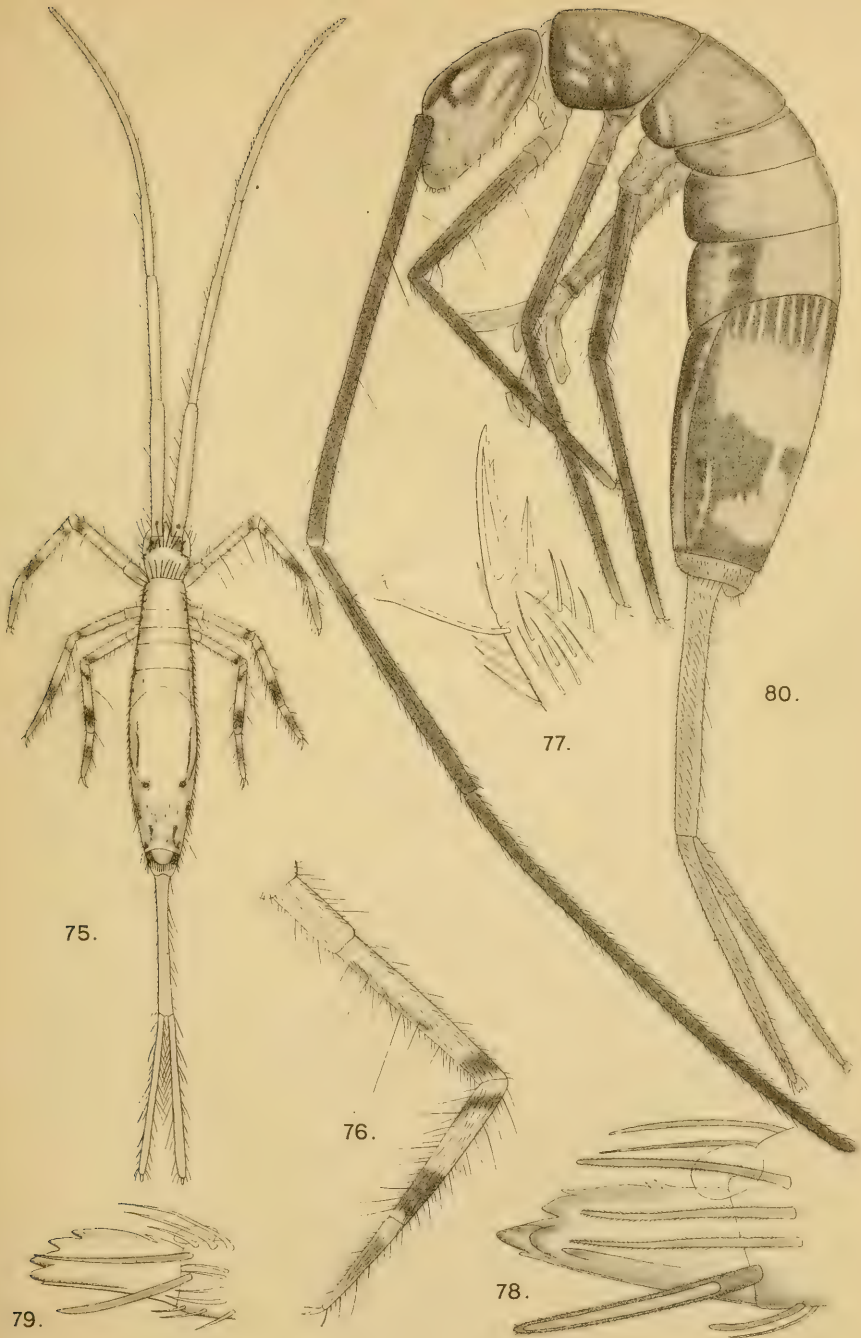
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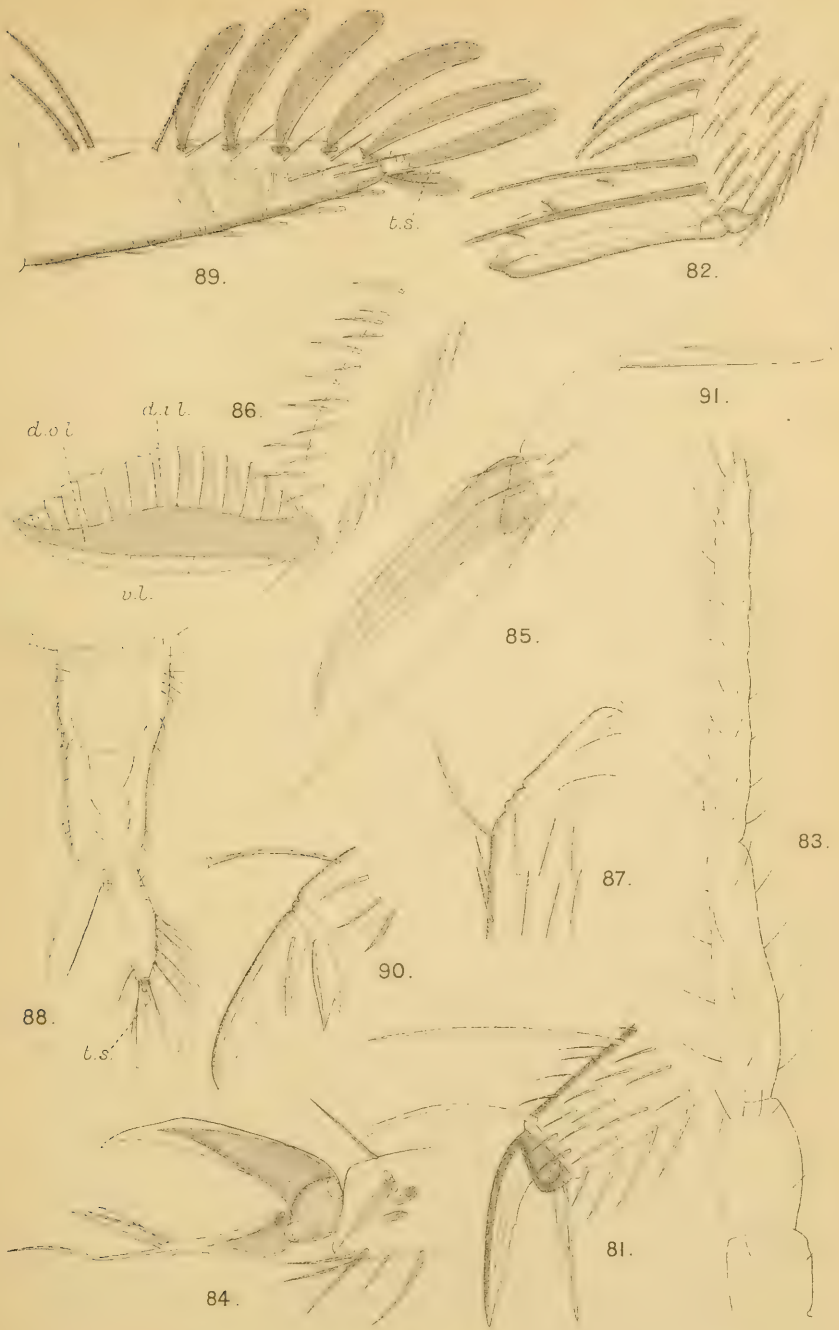
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ORIENTAL COLLEMBOLA.



A.D. Imms ad nat. del.

E. Wilson, Cambridge.

ORIENTAL COLLEMBOLA.

A.—Palæaretic Species.

Entomobrya crassa, sp. n.*Isotoma siva*, sp. n.*Tomocerus vulgaris* Tullb.*Sinella montana*, sp. n.*Seira frigida*, sp. n.

B.—Oriental Species.

Xenylla obscura, sp. n.*Achorutes armatus* Nicolet.*Pseudachorutes anomalus*, sp. n.*Neanura corallina*, sp. n.*N. intermedia*, sp. n.*N. pudibunda*, sp. n.*Isotoma nigropunctata*, sp. n.*Heteromuricus cereifer*, gen. et sp. n.*Isotomurus palustris* Müll.*Lepidocyrtus robustus*, sp. n.*Entomobrya kali*, sp. n.*E. kali* var. *lutea*, nov.*Seira brahma*, sp. n.*Pseudosira indra*, sp. n.*Dicranocentroides fasciculatus*, gen. et sp. n.*Cremastocephalus montanus*, sp. n.*C. indicus*, sp. n.*Paronella börneri*, sp. n.*P. travancorica*, sp. n.*P. gracilis*, sp. n.*P. phanolepis*, sp. n.*P. insignis*, sp. n.*Idiomerus pallidus*, gen. et sp. n.*Cyphoderus simulans*, sp. n.*Pseudocyphoderus annandalei*, gen. et sp. n.*Sminthurides appendiculatus*, sp. n.

The fact that so large a proportion of the species are new is scarcely remarkable, owing to the great diversities of climate and soil found in the various areas from which the specimens were obtained; *vide* text-fig. 14, p. 82.

The limits of the northern boundary of the Oriental zoo-geographical region are difficult to define owing to the fact that members of the Oriental fauna penetrate, in places, for long distances up into the hot confined valleys of the Himalayas; while, on the other hand, the Palæaretic fauna descends the southern slopes of that range to within the limits of forest growth. As Blanford* remarks, above the limit of forests the fauna is purely Palæaretic, all the Oriental types having disappeared. The forest

* "The Distribution of Vertebrate Animals in India, Ceylon, and Burma." Phil. Trans. Roy. Soc. vol. 194, 1901, p. 347.

possessing a median cercus to the fifth segment of the abdomen. A new sub-family—the *Heteromuricinae*—has been created for its reception. A second new genus, *Pseudocyphoderus*, with a single species, occurs in nests of Termites near Lake Chilka.

In no instance has a new genus been created unless I had at my disposal at least five specimens, and many of the new species have only been founded after an examination of a series of twenty or more examples. At least nine apparently new species, and two new genera, have been left undescribed owing to there being, in these particular instances, only one or at the most two specimens of each at my disposal. A few years' experience with the Collembola is sufficient to teach that, apart from colour and size, such structural features as the number of teeth to the claws of the feet, and the relative lengths of the antennal joints, frequently cannot be relied upon for specific purposes, unless several specimens are at hand for comparison.

Unless definitely stated otherwise, the descriptions have been drawn up from specimens preserved in alcohol. In this connection, it is important to take into account the fact that a variable amount of contraction of parts frequently takes place. The relative lengths of the trunk segments, and the joints of the antennæ, are difficult to represent with complete numerical correctness, owing to the contraction (or telescoping) that takes place in many instances from this cause. However, in almost every instance the numerical ratios given in this paper have only been arrived at after having made a series of measurements on several specimens. These measurements were obtained by the aid of a Leitz drawing apparatus and a Zeiss micrometer. In all cases the measurement of the relative lengths of the trunk segments has been taken along the mid-dorsal line of the body.

As regards the terminology employed, I have in every instance used the word *body* to denote the whole insect, excluding, of course, the appendages, and the word *trunk* to mean the thorax and abdomen. As regards the configuration of the *furcula*, I have described that organ in the extended attitude, projecting backwards. The terms *dorsal* and *ventral* and *anterior* and *posterior* are used with reference to the organ in that position. The use of these terms in this connection has been made solely for purposes of description, without any reference to their being of morphological value.

The measurements of the length of the different species refer to the body only, and do not include either the antennæ or furcula.

Owing to the fact that it has not been possible in India to consult certain Papers of the earlier zoological literature, a few of the references to the original descriptions of genera and species have been quoted on the authority of Tullberg's "*Sveriges Podurider*"; these are denoted thus †.

The majority of the specimens are to be found in the collection of the Indian Museum, Calcutta, and the reference numbers to:

that collection are quoted in each case. Wherever material has allowed, a series of co-types has also been deposited in the Natural History Department of the British Museum, South Kensington. Such species are indicated thus*.

II. DESCRIPTION OF THE SPECIES.

Sub-order ARTHROPLEONA Börn.

Fam. PODURIDÆ Lbk.

Sub-fam. HYPOGASTRURINÆ Börn.

Genus XENYLLA Tullb.

†*Xenylla* Tullberg, "Om Skand. Podurider af underfam. Lipurinae," Akad. Afh. Upsala, 1869, p. 11.

**XENYLLA OBSCURA*, sp. n. (Pl. VI. figs. 5-9.)

Dentes furculæ cum mucronibus tibiæ longitudine æquales. Spinae anales parvæ, arcuatæ, papillis crassis affixæ. Pili clavati in tibiis nulli. Long. .75 mm.

Head.—The eyes as in other species of the genus.

Legs.—The claws of the feet all similar, unarmed. Near the apex of each tibia is a slender tapering seta (fig. 9); *tenent hairs* absent.

Furcula.—The *dens* and *macro* together equal to the tibia in length—a little longer than the manubrium. The *mucrones* not fused with the dentes, slender, and very slightly curved at their apices (figs. 5 & 7).

Hamula.—A little shorter than the dens; the *rami* tri-dentate, the innermost tooth the largest (fig. 8).

Anal Spines.—Small and stout, curved. The papillæ from which they arise small and short (fig. 6).

Coloration.—Leaden purple with a number of small irregular yellowish markings on the dorsal aspect of the head and trunk. The legs, furcula, and ventral aspect of the body pale, almost white. The eyes on a black patch on each side of the head.

Length .75-1 mm.; average length .75 mm.

Eighteen specimens from Simla, altitude *circa* 7000 ft., where they were found floating in large numbers on the surface of pools of a stream (*N. Annandale*, May 11th, 1908).

No. $\frac{4390}{16}$ Indian Museum Coll.

This species is a little smaller than most species of the genus. It resembles *Xenylla humicola* (O. Fabr.) Tullb. in having the macro free and not fused up with the dens, though the separation in *X. humicola* is rather more marked when viewed from the dorsal aspect than in the present species. From *X. humicola* it is further distinguished—(a) by the absence of tenent hairs from

the extremity of the tibia; (b) in the combined length of the dens and muero not exceeding that of the tibia; and (c) in the anal spines being larger and more strongly curved. *X. grisea* Axels. and *X. maritima* Tullb. differ from *X. obscura* in having the muero and dens fused together, and in the anal papillæ being larger. *X. brevicauda* Tullb. and *X. nitida* Tullb. are both easily separable from the present species on account of their having a much smaller furcula.

Sub-fam. ACHORUTINÆ Börn.

Genus ACHORUTES Templ.

Achorutes Templeton, "Thys. Hib.," Trans. Ent. Soc. Lond. vol. i. 1835, p. 96 (*ad partem*).

Achorutes Schött, "Zur Syst. und Verbreit. Pal. Collem.," Köngl. Svensk. Vet.-Akad. Handl. 1893, vol. xxv. p. 80.

ACHORUTES ARMATUS Nicolet.

Syn. 1842. *Podura armata* Nicolet, Rech. pour servir à l'hist. des Podur. p. 57, pl. v. fig. 6.

† 1847. *Achorutes armatus* Nicolet, Essai s. classif. de l'ordre des Thys. p. 378.

One hundred and forty specimens, Peradeniya, Ceylon (*E. E. Green*, 1905).

I have compared these specimens with European examples of *Achorutes armatus* and find that they agree in all details of structure. In a letter dated Nov. 2nd, 1907, Mr. E. E. Green remarks that "this little species appears occasionally in vast numbers on the silt left in ditches after rains. It could then be collected by the bucketful. It has a peculiarly unpleasant odour of its own, which it has communicated to the spirit in which it has been preserved."

It has been previously recorded from the Oriental region by Oudemans ‡ from Sumatra.

Sub-fam. NEANURINÆ Börn.

Genus NEANURA Macgillivray.

† *Anoura* Gervais, Une quinz. d'espèces des Ins. Apt., 1842, p. 45.

† *Anura* Nicolet, Essai s. classif. de l'ordre des Thys., 1847, p. 386.

Neanura Macgillivray, "A Cat. Thys. N. America," Can. Ent. xxiii. 1891, p. 267.

* *NEANURA CORALLINA*, sp. n. (Pl. VII. figs. 23-26.)

Latera corporis parvis tuberibus instructa. Unquiculus inermis.

‡ Apterygota des Indischen Arch., in Max Weber's 'Zool. Ergebnisse einer Reise in Nieder.-Ostind.' Hft. i. p. 89.

Organa postantennalia desunt. Ocelli in utroque latere capitis 2. Color corallium. Long. 2-2.3 mm.

Head.—Broader than long, somewhat triangular in form (fig. 23). The *eyes* two in number on either side, situated at the base of a rounded dorsal tubercle which is surmounted by a central seta (fig. 25). *Post-antennal organs* wanting.

Antennae.—Approximately equal in length to the head; the joints related to one another in length as 8 : 11 : 7 : 9. The articulation between the third and fourth joints imperfectly developed, and only visible on the ventral aspect. A small trilobed *sense-organ* at the apex of the terminal joint (fig. 24).

Trunk.—The *segments* mutually related in length as 6 : 8 : 9 : 8 : 8 : 8 : 8 : 6 : 4. The three thoracic segments each provided with a pair of small, dorso-lateral hemispherical protuberances, surmounted by setae. The first three abdominal segments have each a similar pair of protuberances, together with a larger protuberance placed externally to the latter (fig. 23). The lateral margins of the fourth abdominal segment produced into a series of three such protuberances; the fifth and sixth abdominal segments each with a pair of similar bodies, only larger and dorso-lateral in position. The *cuticle* investing the body and appendages ornamented with minute closely-set tubercles (fig. 25).

Legs.—Short and stout, sub-equal in size; the hind pair of tibiae as long as the femora, the tibiae of the first and second pairs of legs shorter than the femora (fig. 26). The *claws* alike, large and stout, slightly curved and minutely tuberculated; teeth wanting.

Coloration.—Bright coral-red when alive (*Green*), but the pigment is completely soluble in alcohol, giving the latter a pinkish-orange colour.

Length 2-2.3 mm.

Fifty-two examples from Peradeniya, Ceylon, 1500 ft., where it is common under stones, logs of wood, and dead leaves (*E. E. Green*).

No. $\frac{4386}{16}$ Indian Museum Coll.

The relative lengths of the joints of the antennae and legs exhibit considerable diversity in alcohol specimens owing to the variable amount of contraction undergone.

NEANURA PUDIBUNDA, sp. n. (Pl. VI. figs. 10-12.)

Organum postantennale ellipticum, inchoatum. Ocelli in utroque latere capitis 3. Unguiculus superior uno dente armatus, inferior inchoatus. Color coccineus. Long. 1.5-2.25 mm.

Head.—Somewhat broader than long, triangular. *Eyes* spherical, three on each side. The *post-antennal organs* rudimentary and appear to be represented by a patch of modified cuticle close to the outer side of each group of eyes (fig. 10).

Antennae.—In length very nearly equal to the head; the articulation between the third and fourth joints imperfectly

developed, and only noticeable on the ventral aspect. The second joint the longest; the fourth joint with a small trilobed apical sense-organ (fig. 10).

Trunk.—The segments related to one another in length as 4 : 7 : 7 : 6 : 6 : 6 : 6 : 7 : 6, and provided with lateral tufts of long setæ. The postero-lateral margins of the fifth abdominal segment produced into a setigerous protuberance on either side; the sixth abdominal segment with a pair of such protuberances on each side (fig. 12).

Legs.—Short and subequal. The superior claw provided with a single tooth on the inner margin near the base. The inferior claw probably represented in a vestigial condition by a small basal process (fig. 11).

Coloration.—Scarlet when alive (*Annandale*); specimens in alcohol are white.

Length 1.5–2.25 mm.

Eight specimens taken on bats' dung in total darkness in the Khayon Caves, near Moulmein, Lower Burma (*N. Annandale*, March 7th, 1908).

No. $\frac{4385}{16}$ Indian Museum Coll.

Dr. Annandale informs me that the Khayon Caves are of no great extent, though their inner parts are quite dark. There are no features about *Neanura pudibunda* that point to its being a true cave form, and most probably it is only a recent migrant thither.

* *NEANURA INTERMEDIA*, sp. n. (Pl. VI. figs. 13, 14; Pl. VII. fig. 20.)

Tubera corporis desunt. Unguiculus inermis. Organa post-antennalia nulla. Ocelli in utroque latere capitis 2. Color corallium. Long. 2 mm.

This species differs from *Neanura corallina*, sp. n. in the absence of dorso-lateral protuberances from the body, and in possessing longer setæ to the antennæ. From *Neanura pudibunda*, sp. n. it differs in the number of the eyes and in the absence of the tooth from the inner margin of each of the claws of the feet (fig. 14).

It resembles *Neanura corallina* very closely in the important structural features of the claws of the feet, the number of the eyes, and the absence of post-antennal organs. It resembles *Neanura pudibunda* in possessing two pairs of terminal setigerous protuberances to the abdomen, in the absence of the dorso-lateral protuberances from the abdomen, in the length and general disposition of the setæ on the antennæ (fig. 13), and in the general form of the body. It is thus intermediate in its characters between the two preceding species of the genus, though it differs from both in the above mentioned features.

Colour.—Coral-red; in alcohol specimens quite white.

Length 2 mm.

Eleven specimens from near Bhowali, Naini Tal District, in

the Himalayan foot hills of Kumaon, *circa* 5000 ft. It is very local, and occurs under damp loose bark and in decaying stems of *Euphorbia* (A. D. Imms, July 1909).

No. ⁴³⁸⁹/₁₆ Indian Museum Coll.

A Key to the three Species of the Genus *Neanura*.

- A. Ocelli two on each side of the head. No post-antennal organs.
 1. Body without dorso-lateral protuberances *N. intermedia*.
 2. Dorso-lateral protuberances present *N. corallina*.
 B. Ocelli three on each side of the head. Post-antennal organs
 present *N. pudibunda*.

Oudemans* has described a single species of this genus (*N. fortis*) from the Oriental region, where it occurs in Java, Sumatra, and Saleyer.

Genus PSEUDACHORUTES Tullb.

Pseudachorutes Tullberg, "Fört. öfver Sv. Podurider," Öfvers. Kongl. Vet.-Akad. Förbandl. xxvii. 1871, p. 155.

Pseudachorutes Börner, "Das System der Collembolen," Mitt. Naturhist. Mus. Hamburg, xxiii. 1906, p. 164 (= ? *Gnathcephalus* Macg.).

PSEUDACHORUTES ANOMALUS, sp. n. (Pl. VI. figs. 1-4.)

Corpus tuberculatum. *Tumores utriusque organi post-antennalis*
 17. *Unguiculus inermis*. *Pili clavati in tibiis nulli*. *Antennarum articulus quartus duobus præcedentibus longior*. Long. 1-1.25 mm.

Head.—The eyes eight in number on each side. *Post-antennal organs* oval in form, each with seventeen tubercles (fig. 2).

Antennæ.—The joints related in length to one another as 5 : 6 : 4 : 11; the third and fourth joints partially fused together; a small tri-lobed *apical sense-organ*, and a second sense-organ situated a short distance below the apex of the antenna. Invested with a few short slender hairs; the cuticle tuberculated.

Trunk.—Almost entirely glabrous, only a few odd scattered hairs being present. The cuticle uniformly tuberculated (fig. 2).

Legs.—Short and stout; the cuticle not tuberculated. A few scattered setæ on the femora and basal joints, and a double circlet of setæ near the distal extremity of each tibia. The *claws* similar on each pair of legs, large and stout, more than one half the length of the tibia, unarmed (fig. 3). *Tenent hairs* absent.

Furcula.—Short and stout (fig. 4), not quite reaching up to the apex of the abdomen; the cuticle uniformly tuberculated. The *manubrium* and *dentes* about equal in length, and each approximately two and a half times the length of the mucro. The *mucro*

* Oudemans in Weber's 'Zool. Ergeb. einer Reise in Nederland.-Ostind.' Hft. i. p. 91.

(fig. 1) large and blade-like, its surface partially sculptured with small tubercles similar to those found elsewhere; at its apex is a rounded curved tooth.

Coloration.—In alcohol specimens dull brick-red above and pale dirty cream-colour beneath; the antennæ somewhat darker than the rest of the body and with a purplish suffusion. The legs and furcula whitish.

Length 1·1–2·5 mm.

Two specimens taken on the surface of water at Kurseong, E. Himalayas, 5000 feet (*N. Annandale*, July 4th, 1908).

No. $\frac{4395}{16}$ Indian Museum Coll.

This species differs from Tullberg's original diagnosis of the genus in having the cuticle of the whole of the body and appendages, with the exception of the legs, tuberculated.

Family ENTOMOBRYIDÆ D. T.

Sub-fam. ISOTOMINÆ Schöff.

Genus ISOTOMA Bourlet.

Isotoma Bourlet, Mém. sur les Podures, 1839, p. 23 (*ad partem*).

ISOTOMA SIVA, sp. n. (Pl. VI. figs. 16–18; Pl. VII. fig. 19.)

Setosa. *Segmentum quartum abdominis triplo longius quam tertium*. *Antennæ capite duplo longiores; articulus quartus tertio fere duplo longior*. *Ocelli 12: 6 in utroque latere capitis*. *Organum postantennale nullum*. *Dentes mucronum tres, unus post alterum inserti*. *Long.* 1·25–1·5 mm.

Head.—Slightly longer than broad, as long as the thorax (fig. 19). The eyes six in number on each side (fig. 18); *post-antennal organs* wanting.

Antennæ.—In average length measuring ·5 mm.; the joints related to one another proportionately in length as 5: 8: 8: 14.

Trunk.—The segments related to one another in length as 9: 8: 5: 5: 7: 7: 20: 5: 1 (fig. 19). Invested with plumose hairs.

Legs.—Sub-equal, clothed with plumose hairs; the claws to each of the pairs similar. The *superior claw* elongate and greatly acuminate, with two extremely minute teeth near the apex, and a third tooth near the base. The *inferior claw* unarmed. A single very long *tenent hair* in relation with each foot (fig. 16).

Furcula.—Approximately equal in length to the antennæ; clothed with plumose hairs. The *dentes* one half longer than the *manubrium*. The *mucrones* small, tridentate; provided with a prominent, upwardly directed terminal tooth, and immediately in front of it is a second tooth pointing obliquely forwards, and in close relation with the latter is a backwardly directed spiniform tooth (fig. 17).

Coloration.—When alive dull reddish with a purplish tinge. In alcohol specimens dull brick-red, with the head paler and inclining to yellowish. The antennæ and legs dark purplish; the furcula white. The eyes on a black patch on each side of the head, the two eye-patches united together by a transverse black band situated just behind the points of origin of the antennæ (fig. 19).

Length 1.25–1.5 mm.

Five specimens taken under stones along the edge of a mountain stream at Badrinath, Garhwal Himalaya, 10,300 ft. (A. D. Imms, May 27th, 1910).

No. $\frac{8605}{16}$ Indian Museum Coll.

ISOTOMA NIGROPUNCTATA, sp. n. (Pl. VII. figs. 27–29.)

Setosa. *Segmentum quartum abdominis fere triplo longius quam tertium*. *Ocelli 4:2 in utroque latere capitis*. *Dentes furculæ manubrio longiores; mucrones tridenticulati*. *Long. 1.5–2 mm.*

Head.—The eyes two in number on each side, placed one behind the other. The *post-antennal organs* very small, annular (fig. 27). Situated on the dorsal aspect of the head are large curved setæ, ciliated along one side at their apices.

Antennæ.—Slightly longer than half the total length of the head and trunk; the joints related to one another in length as 3:6:6:11.

Trunk.—The segments related respectively in length as 6:5:3:4:5:13:3:1. A prominent “collar” of setæ along the anterior border of the mesothorax, similar to those occurring on the head. A few scattered setæ over the general surface of the body, and a tuft of plumose hairs at the apex of the abdomen.

Legs.—The claws of the feet similar on each pair of legs (fig. 28). The *superior claw* slender, strongly curved and acuminate; armed with one large tooth towards the base, and a minute tooth immediately in front of the latter. The *inferior claw* linear and acuminate, unarmed. No *tenent hairs*; in the position occupied by them is a slender tapering seta.

Furcula.—Slender, the *dentes* related in length to the *manubrium* as 5:4. The *mucrones* (fig. 29) tridentate, armed with a slender curved terminal tooth, in front of the latter is a shorter and stouter vertical tooth, and at the base of the mucro is a slender backwardly directed spiniform tooth. Arising from the dens, at a distance from the apex equal to three times the length of the mucro, are several long compound (plumose) hairs. These extend backwards, parallel with the long axis of the furcula, reaching nearly to the apex of the mucro (fig. 29).

Coloration.—Straw-coloured with a slight brownish tinge; the legs and spring whitish. When viewed under an $\frac{1}{8}$ in. objective deposits of fine brown granules are seen beneath the cuticle, and to these the brownish tinge owes its origin. The deposits are for the most part arranged segmentally in transverse bands. The

eyes densely pigmented, appearing as two black dots on each side of the head.

Length 1.5–2 mm.

Three examples, taken under stones at the edge of a spring in the Kurseong District, E. Himalayas, 4700 feet (*N. Annandale*, March 25th, 1910).

No. $\frac{8603}{16}$ Indian Museum Coll.

This species is readily distinguishable from *Isotoma quadri-oculata* Tullb. by the fact that the dentes are much longer than the manubrium, and that the mucrones are tridentate.

Sub-fam. TOMOCERINÆ Schöff.

Genus TOMOCERUS Nicolet.

Tomocerus Nicolet, Rech. p. serv. à l'hist. des Podur., 1841, p. 67.

TOMOCERUS VULGARIS Tullb.

Syn. 1871. *Macrotoma vulgaris* Tullberg, "Fört. öfver Sv. Podurider," Öfvers. Kongl. Vet.-Akad. Förhandl. xxvii. p. 149.

1893. *Tomocerus vulgaris* Schött, "Zur Syst. und Verbreit. Palæarc. Coll.," Kongl. Svenska Vet.-Akad. Handl. xxv. p. 41.

A form closely resembling the type species and differing only in the following points:—

- a. Smaller in size.
- b. Ten instead of 12–16 spines to the dentes.
- c. The basal tooth of the mucro larger and more pointed than is represented in Tullberg's figure of *T. vulgaris* *.

Length 3 mm.

Two specimens, taken under stones near the edge of a mountain stream at Badrinath, Garhwal Himalaya, 10,300 feet (*A. D. Imms*, May 27th, 1910).

No. $\frac{8612}{16}$ Indian Museum Coll.

In both examples the antennæ possessed only three joints, which were related to one another in length as 7 : 12 : 70. The antennæ themselves measured 2.2 mm. long.

On account of the small size of the specimens and their possessing only three joints to the antennæ, instead of the normal number of four, I believe that they are immature individuals of the above species. They are probably to be regarded as a Himalayan variety of the same, but this point cannot be definitely determined until adult specimens have been discovered.

Sub-fam. HETEROMURICINÆ, sub-fam. nov.

This sub-family is characterised by the presence of a median cercus to the fifth abdominal segment.

* Sveriges Podurider, pl. iv. fig. 9.

Genus *HETEROMURICUS*, gen. nov.

Mesonotum non prominens. Segmentum abdominale quartum quam tertium paullo longius. Antennæ quinque articulos habent. Ocelli 16: 8 in utroque latere capitis. Organa postantennalia carent. Segmentum abdominale quintum medio cerco instructum. Cutis squamosa.

The presence of a single median cercus to the fifth abdominal segment separates this genus from other known genera of Collembola. In possessing five-jointed antennæ, and in the body being scaled, it shows perhaps closer relations with *Heteromurus* Wankel than with any other genus.

* *HETEROMURICUS CERCIFER*, sp. n. (Pl. VIII. figs. 49-51; Pl. IX. figs. 52-54.)

Antennarum articulus quartus longissimus, quam tertius duplo longior. Cercus segmento abdominali tertio longitudine æqualis. Unguiculus superior duobus minutis dentibus armatus; unguiculus inferior lanceolatus, acuminatus, inermis. Mucrones dentibus duobus atque seta spiniforme una instructi. Long. 2 mm.

Head.—Inclined at an angle of 45° with the long axis of the body; invested with scales and scattered setæ. The eyes eight in number on each side; *post-antennal organs* wanting.

Antennæ.—Equal in length to the furcula; five-jointed (fig. 52), the joints respectively related in length as 1:10:12:25:14. The basal joint small and annular, provided with a whorl of short spine-like setæ; the second and third joints scaled; the fourth and fifth joints clothed with closely-set whorls of short, curved hairs.

Trunk.—Densely clothed with *scales* (figs. 51 and 52); the scales at the hinder extremity of the body, surrounding the base of the cercus, larger than those found elsewhere. The *segments* mutually related in length as 6:6:5:6:8:12:4:1. Arising from the dorsal aspect of the fifth abdominal segment is a prominent median *cercus* (figs. 50 and 52) nearly equal in length to the third abdominal segment. The cercus densely clothed with scales, and provided ventrally with long slender setæ, possibly sensory. Along the anterior border of the mesothorax is a "collar" or "frill" of stout setæ, and a tuft of similar setæ at the extremity of the abdomen,

Legs.—Sub-equal; the two basal joints clothed with setæ, the remaining joints scaled down to the claws; interspersed among the scales are numerous hairs and setæ (fig. 49). The *superior claws* of the feet with two small teeth along the inner margin (in five specimens one or other of the teeth were absent). The *inferior claws* large, lanceolate and acuminate, unarmed; those of the third pair of legs a little longer than the corresponding claws of the preceding pairs.

Furcula.—Slender, reaching forwards to the ventral tube; densely clothed ventrally with scales. The *dentes* related in

length to the *manubrium* as 4 : 3. The *mucrones* small, armed with a curved terminal tooth, a single dorsal tooth and a basal spiniform tooth (fig. 54).

Coloration.—Ground-colour of the body and furcula varies from whitish to dull ochre-yellow; the legs, antennæ, and cercus bluish-violet. The eyes on a black patch on each side of the head. The ground-colour of the body varies according to whether the specimens have been denuded of their scales or not.

Length varying from 1.5–2.5 mm. (excluding cercus); average length 2 mm.

Thirteen specimens, taken under dead leaves at Calcutta (*Indian Museum Collector*, Jan. 14th–20th, 1908, and Feb. 18th, 1910).

No. $\frac{445}{16}$ Indian Museum Coll.

Sub-fam. ENTOMOBRYINÆ Schöff.

Genus ISOTOMURUS Börn.

Isotomurus Börner, "Neue altw. Collem., nebst Bemerk. z. Syst. der Isotom. und Entomob.," Sitz. Gesell. naturf. Freunde zu Berlin, 1903, p. 129.

* ISOTOMURUS PALUSTRIS Müll. (Pl. VI. fig. 15; Pl. VII. figs. 21, 22.)

† Syn. 1776. *Podura palustris* Müller, Zool. Dan. Prodr., Havniæ, p. 184.

1873. *Isotoma palustris* Lubbock, Monogr. Coll. and Thys. p. 169.

Head.—The *eyes* eight in number on each side (fig. 22).

Antennæ.—A little longer than the thorax, the joints related proportionately in length as 4 : 8 : 9 : 9 (in one example they were related as 3 : 6 : 7 : 8).

Trunk.—Clothed with plumose hairs. The third abdominal segment a little longer than the fourth.

Furcula.—As long as, or a little longer than the antennæ; reaching to the ventral tube. The *dentes* approximately twice the length of the *manubrium*.

Coloration.—Ochre-yellow, either with or without a few small irregular scattered black markings on the dorsal aspect, which coalesce in some specimens to form blotches. The antennæ and furcula paler; the antennæ in two examples tinged with purple.

Length 2 mm.

Ten specimens, taken on the surface of water at Calcutta ‡ (*Indian Museum Collector*, Sept. 1st, 1908, and Sept. 22nd, 1909).

No. $\frac{4393}{16}$ Indian Museum Coll.

The specimens agree in all essential details of structure with European forms of the species.

‡ *I. palustris* has been previously recorded from the Oriental region by Börner, from Java.

Genus LEPIDOCYRTUS Bourlet.

Lepidocyrtus Bourlet, Mém. s. les Podurelles, 1839, p. 15.

Lepidocyrtus Börner, "Das System der Coll.," Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. pp. 164 and 174. [Including *Pseudosinella* Schäff. and *Acanthurella* Börn.]

LEPIDOCYRTUS ROBUSTUS, sp. n.

Segmentum abdominale quartum, thoracem, et segmentum abdominale primum longitudine æquans. Unguiculus superior dentibus duobus parvis armatus; unguiculus inferior lanceolatus, inermis. Long. 3.6 mm.

Antennæ.—Three times longer than the head, the joints related to one another in length as 2 : 3 : 3 : 4.

Trunk.—The segments related respectively as 16 : 6 : 4 : 5 : 4 : 26 : 2 : 1. The fourth abdominal segment six times the length of the preceding segment.

Legs.—The claws similar on each of the pairs of legs; the superior claw armed with two small teeth situated respectively from the base and apex of the claw, at distances equal to one third the length of the latter. The inferior claw lanceolate, unarmed. A single tenent hair in relation with each foot.

Furcula.—The denticles very nearly twice the length of the manubrium; the mucrones tridentate, similar to the typical form found in the genus.

Coloration.—The ground colour yellowish, the appendages paler. The third joint of the antennæ with an apical suffusion of violet-black, the fourth joint almost white with a slight basal suffusion of violet. The eyes on a black patch on each side of the head; a purplish lateral suffusion on each side of the head behind the eye-patch. An extensive suffusion of the same colour on either side of the mesothorax, and a broad conspicuous band of similar colour along the distal portion of the fourth abdominal segment. The femora of the hind pair of legs almost entirely violet.

Length 3.6 mm. (including the head).

One example, taken under dry leaves and stones on the edge of a jungle stream, Maddathoray, W. base of W. Ghats, Travancore, S. India (*N. Annandale*, November 18th, 1908).

No. $\frac{8611}{16}$ Indian Museum Coll.

This species is closely allied to *L. maximus* Schött*, from the Kamerun. It is separable, however, on account of the great size of the fourth abdominal segment; in the inferior claws of the feet being lanceolate, with its lower margin curved instead of being straight; and in the stouter tenent hair.

* "Insektenfauna von Kamerun: Collembola," Bihang till K. Sv. Vet.-Akad. Handl., Bd. 19, Afd. iv. no. 2, p. 11, pl. iii.

Genus ENTOMOBRYA Rondani.

† *Entomobrya* Rondani, Dipterol. Ital. Prodr. vol. iv.

Degeeria Nicolet, Rech. p. s. à l'hist. d. Podur., 1842, p. 70.

Entomobrya Börner, "Das Syst. Coll.," Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 164. [Including *Homidia* Börner and *Sinella* Brook.]

* ENTOMOBRYA KALI, sp. n. (Pl. VII. fig. 33; Pl. VIII. figs. 34-36.)

Antennae truncum longitudine fere æquantes. Segmentum abdominale quartum plus dimidia trunci parte occupans. Mucrones denticulis duobus atque seta spiniforme una instructi. Flava; anteriore parte capitis, marginibus segmenti secundi thoracis, segmentis secundis tertiisque abdominis, et fascia transversa posteriore quarti, nigris. Long. 1.75-2 mm.

Head.—Slightly longer than broad; clothed with short, scattered plumose hairs and a dorsal tuft of very long, stout setæ, ciliated along one side at their apices. The *eyes* eight in number on each side.

Antennae.—Usually very nearly equal in length to the body excluding the head, but in some specimens they exceed the length of the body. Four jointed, densely clothed with hairs, dispersed among which are slender setæ. The joints related to one another in length as 5 : 6 : 6 : 11; the ring-like basal joint, typically present in the genus *Entomobrya*, is absent.

Trunk.—Fusiform, clothed with short, curved plumose hairs, scattered among which are slender setæ. The thorax and first two abdominal segments provided dorsally with very long, stout setæ, ciliated along one side at their apices (fig. 36); a tuft of similar setæ at the apex of the abdomen. The trunk segments related proportionately in length as 11 : 5 : 3 : 6 : 6 : 45 : 5 : 1 (fig. 34).

Legs.—Clothed with hairs among which are slender setæ. The *superior claws* moderately slender and bidentate along the inner margin (fig. 33); the teeth situated respectively from the apex of the claw at a distance equal to one quarter and one half the total length of the latter. The *inferior claws* a little more than half the length of the superior claws, acuminate and sharply pointed, the margins without any teeth. A single *tenent hair* in relation to each foot.

Furcula.—As long as the trunk excluding the mesothorax; densely clothed with hairs, dispersed among which are slender setæ. The *dentes* a little longer than the *manubrium*, very slender, and each is provided with a double row of small peg-like spines along the proximal half of its inner aspect. The *mucrones* tridentate, with a curved terminal tooth, a stout erect conical middle tooth, and an oblique acicular posterior tooth (fig. 35).

Coloration.—Light ochre-yellow marked with patches of violet-black. The eyes on a large irregular black area on each side; a

small violet-black patch between the bases of the antennæ and frequently prolonged into a narrow streak on each side to unite with the eye-patch. A triangular area of the same colour on the middle of the hind border of the mesothorax, and a slight suffusion on each side near the outer margin of that segment. The metathorax and the first abdominal segment entirely yellow; the second abdominal segment violet-black, with the exception of a narrow irregular yellow area along its anterior margin; the third abdominal segment entirely deep violet-black; the posterior half of the fourth abdominal segment densely suffused with violet-black; the fifth and sixth abdominal segments yellow. The first and second joints of the antennæ yellow, the second joint in most specimens with a slight violet suffusion at its apex; the third and fourth joints purplish.

Length 1.75–2 mm.

Fifty-one specimens taken under dead leaves in Calcutta, where it appears to be very plentiful (*Indian Museum Collector*, January 16th, 17th, 18th, and 20th, 1908, and February 18th, 1910).

Nos. $\frac{4383}{16}$ and $\frac{4384}{16}$ Indian Museum Coll.

In all the individuals examined the colour pattern was found to be very constant, practically no variation being observed. In specimens that had been kept in alcohol for two years, the ground colour is much paler and cream-coloured. The long, stout setæ (fig. 36) fall off very readily in alcohol specimens, and very many specimens have lost them altogether. In many cases the antennæ are very much shrivelled in alcohol, and in a large proportion of the specimens the tenent hair is either broken or lost from one or more of the legs.

ENTOMOBRYA KALI LUTEA, var. nov.

This differs from the typical form in having the fourth abdominal segment entirely yellow.

One specimen taken among low herbs and grass at Simla *circa* 7000 ft. (*N. Annandale*, May 12th, 1908).

No. $\frac{8614}{16}$ Indian Museum Coll.

ENTOMOBRYA CRASSA, sp. n. (Pl. VII. figs. 30, 31.)

Segmentum tertium abdominis quartum longitudine fere æquans. Mucrones denticulis duobus atque seta spiniforme una instructi. Color flava-viridis. Long. 1.5 mm.

Head.—The eyes eight in number on each side (fig. 31); the post-antennal organs wanting.

Antennæ.—The joints mutually related in length in the proportion of 4 : 6 : 6 : 9.

Trunk.—Provided with pilose hairs of various lengths. The segments related to one another in length as 8 : 7 : 4 : 5 : 8 : 10 : 3 : 2.

Legs.—Clothed with pilose hairs among which are a few stouter

setæ. The *superior claw* of each foot slender and acuminate, with a small tooth situated at the middle of the inner margin. In some examples there is a second, and much smaller tooth, placed half way between the former tooth and the apex of the claw. The *inferior claw* of each foot slender and tapering, a little more than half the length of the superior claw, unarmed. A single very slender *tenent hair* to each foot.

Furcula.—7-9 mm. long; the *manubrium* one half the length of the *dens*. The *mucro* $\frac{1}{50}$ mm. long (fig. 30), tridentate, with a slender, curved terminal tooth, a vertical and somewhat stouter tooth anterior to the latter, and a minute backwardly directed spiniform tooth.

Coloration.—When alive, dull dark green to the naked eye. In alcohol specimens, pale greenish yellow suffused with dark indigo-blue. The eyes on a black patch on each side of the head, the two patches joined together by a transverse band, which passes across the head just behind the bases of the antennæ. On the middle of the dorsal side of the head is a prominent black sagittate marking thus ↓, with its apex directed backwards. The antennæ and legs darker than the body, somewhat purplish in colour. The furcula yellowish white.

Length varying from 1.5-1.8 mm.

Six examples, taken in ants' nests under stones about half a mile below the base of the Satopanth Glacier, Garhwal Himalaya, 12,500 ft. (*A. D. Imms*, May 25th, 1910).

No. $\frac{8609}{16}$ Indian Museum Coll.

This species differs from typical members of the genus *Entomobrya*, and resembles the genus *Orchesella*, in the very short fourth abdominal segment. It agrees with the genus *Entomobrya* in the characters of the antennæ and furcula, in the eyes, and in the absence of post-antennal organs. *Entomobrya anomala* Carpenter* similarly possesses a relatively short fourth abdominal segment. The latter species, however, may ultimately be separated into a new genus on account of its possessing six-jointed antennæ.

Genus SEIRA Lubbock.

Seira Lubbock, "Notes on the Thysanura," pt. iv., Trans. Linn. Soc. 1870, vol. xxvii, p. 279, pl. 45 (= *Ptenura*, Templ., Börn.).

Sira Tullberg, "Sveriges Podurider," Kongl. Svensk. Vetensk.-Akad. Handl. 1872, vol. x, p. 41, pl. vi.

SEIRA FRIGIDA, sp. n. (Pl. VIII. figs. 41, 42.)

Unguiculus superior tridenticulatus; denticuli perparvi, ita collocati ut unus post alterum insertus sit. Unguiculus inferior lanceolatus, inermis. Mucrones breves, bidentati. Articulo quarto

* "On two new Irish species of Collembola," Sci. Proc. Roy. Dublin Soc. vol. xi, (n. s.) 1906, p. 40, pl. ii.

antennarum primum et secundum longitudine æquante. Tibiæ pilis clavatis singulis instructæ. Long. 2.5 mm.

Head.—As long as the combined length of the meso- and metathorax. The eyes as usual in the genus.

Antennæ.—Equal in length to the furcula (in some examples slightly shorter than that organ). The joints related to one another in length as 5 : 8 : 9 : 13.

Trunk.—Invested with scales, among which are prominent curved setæ, ciliated at their apices along one side, and disposed in the following manner : a prominent "frill" or "collar" along the anterior border of the mesothorax, and a second group of such setæ near the posterior margin of that segment. A few scattered setæ on the metathorax, and a tuft of similar but shorter setæ at the extremity of the abdomen. The segments related to one another in length as 8 : 6 : 5 : 5 : 5 : 23 : 5 : 3.

Legs.—The claws of the feet similar on all pairs of legs (fig. 41). The *superior claws* moderately slender, slightly curved at their extremity, and armed with three minute teeth along the inner margin. The *inferior claws* lanceolate, entire, slightly curved at their apices. A *single tenent hair* in relation to each foot.

Furcula.—In length measuring .8 mm.; the *manubrium* related to the *dentes* in length as 13 : 19—or approximately as 2 : 3. The *dentes* without ventral scales; slightly curved upwards at their apices (fig. 42). The *mucrones* only imperfectly separated off from the *dentes*, armed with a prominently curved terminal tooth and a basal spiniform tooth. The latter directed backwards in an oblique fashion, almost reaching to the apex of the mucro (fig. 42).

Coloration.—Dirty yellowish white, marked with irregular patches of blue-black disposed in the following manner:—A prominent patch on either side of the head enveloping each eye-group, and united by a transverse band, which crosses the head immediately behind the bases of the antennæ. A slender Y-shaped marking on the middle of the dorsal aspect of the head. A pair of irregular lateral patches on the metathorax and on the first three abdominal segments; the third abdominal segment with a median unpaired patch near its posterior border. The fourth abdominal segment marked with several irregular lateral and median areas partially confluent with one another, and varying in different specimens; a short transverse band near the posterior end of the segment. The fifth abdominal segment with a pair of prominent lateral patches near its posterior margin. The sixth abdominal segment with a pair of small lateral spots.

The legs, antennæ, and furcula yellowish white, similar to the ground colour of the body. The antennæ and legs conspicuously marked with blotches of blue-black; in one very dark example these markings on the antennæ were confluent, the latter appearing entirely blue-black.

Length varies from 2·1–2·8 mm.

Four specimens, taken in ants' nests under stones on a mountain side a short distance below the base of the Satopanth Glacier, Garhwal Himalaya, *circa* 12,300 ft. (*A. D. Imms*, May 27th, 1910).

No. $\frac{8608}{16}$ Indian Museum Coll.

In one example the lateral blue-black markings on the metathorax and the first abdominal segment, together with the median posterior patch on the third abdominal segment, were entirely absent.

SEIRA BRAHMA, sp. n. (Pl. VIII. figs. 43, 44,)

Unguiculus superior bidenticulatus; *unguiculus inferior lanceolatus*, *inermis*. *Articulus quartus antennarum longissimus*, *secundus et tertius inter se longitudine sub-æquales*. *Mucrones breves tridentati*. *Tibiæ pilis clavatis singulis instructæ*. *Long.* 1·5 mm.

Head.—The *eyes* eight in number on each side, the anterior four in each group the largest. No *post-antennal organs* present.

Antennæ.—A little longer than half the length of the body, the joints related in length to one another as 3 : 8 : 8 or 9 : 14.

Legs.—The claws of the feet similar on each of the pairs of legs (fig. 43). The distal extremity of each tibia provided with a single extremely slender *tenent hair*. The *superior claws* armed with two small teeth, one of which is situated from the base at a distance equal to one third the total length of the claw. The other tooth is situated at a similar distance from the apex of the claw. The *inferior claws* lanceolate and unarmed.

Furcula.—Reaching to the ventral tube; slender. The *dentes* related in length to the *manubrium* as 6 : 5; tapering to their extremities. The *mucrones* tridentate, armed with a curved upwardly directed terminal tooth, a median tooth slightly inclined in a forward direction, and a backwardly directed basal spiniform tooth (fig. 44).

Coloration.—Ground colour pale yellowish dusted over with indigo-blue, the insect appearing slate-grey under a hand-lens. The antennæ indigo-blue, the legs and furcula whitish. The intersegmental areas of the body yellowish. The eyes on a black patch on each side of the head.

Length 1·5 mm.

Five examples, taken crawling up the surface of whitewashed walls in a bungalow at Allahabad (*A. D. Imms*, September 20th, 1907).

No. $\frac{8601}{16}$ Indian Museum Coll.

Genus PSEUDOSIRA Schött.

Pseudosira Schött, "Insektenfauna von Kamerun: Collembola," Bihang till K. Svensk. Vet.-Akad. Handl, 1893, Bd. 19, Afd. iv, p. 10, taf. ii. figs. 1–11.

Pseudosira Börner, "Das Syst. Coll.," Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 164 (including *Mesira* Stscherbakow [= *Lepidocyrtinus* Börner]).

* *PSEUDOSIRA* INDRA, sp. n. (Pl. VII. fig. 32; Pl. VIII. figs. 37-40.)

Unguiculus superior tridenticulatus; denticuli perparvi, ita collocati ut unus post alterum insertus sit. Unguiculus inferior lanceolatus, inermis. Mucrones breves, falciformes. Tibiæ pilis clavatis singulis instructæ. Articulo quarto antennarum longissimo, primum et secundum longitudine æquante. Long. 1.5 mm.

Head.—A little longer than the mesothorax; clothed with scales, among which on the dorsal aspect are long stout setæ, ciliated along one side at the apex. The eyes eight in number on each side; no post-antennal organs (fig. 37).

Antennæ.—As long as, or, in some examples, a little longer than the furcula. The joints related respectively in length as 4 : 7 : 7 or 8 : 11. The first two joints clothed with scales, the third and fourth joints clothed with small hairs.

Trunk.—Clothed with scales of somewhat variable shape, but for the most part oval or linear-oval. The scales are finely and faintly striated, with a relatively long, and very slender pedicel (fig. 40). Setæ (fig. 39), similar to those found on the head, form a kind of "frill" or "collar" along the anterior edge of the mesothorax; a few are also scattered over the general surface of the body, and there is a terminal tuft at the extremity of the abdomen. The trunk segments mutually related in length as 7 : 5 : 4 : 4 : 6 : 15 : 3 : 1.

Legs.—All the feet similar; the distal extremity of each tibia provided with a single *tenent hair*. The *superior claws* slender and acuminate, armed with three small teeth along their inner margin. The *inferior claws* linear and acuminate, acicular, unarmed (fig. 38).

Hamula.—The *corpus* with a median stout anterior seta placed in front of the rami. Each *ramus* quadridentate.

Furcula.—Slender, reaching to the ventral tube. The *manubrium* somewhat shorter than the dentes; scaled. The *dentes* clothed ventrally with scales. The *mucrones* hook-shaped (fig. 32).

Coloration.—Greyish white when denuded of the scales; when the greater number of the scales are present the ground colour appears markedly brown. The antennæ tinged with violet, a slight violet suffusion on the mesothorax, and some small lateral patches of the same colour on either side of the abdomen. The furcula white. The eyes on a black patch on each side of the head.

Length varies in different examples from 1.25-2 mm.

Five specimens on the surface of the pool in the "compound" of the Indian Museum, Calcutta (A. D. Imms, December 31st, 1909). The specimens were apparently immature.

No. $\frac{8602}{16}$ Indian Museum Coll.

Thirty specimens taken under dead leaves and at the bases of the leaves of a palm tree, in the "compound" of the Indian Museum, Calcutta (*Indian Museum Collector*, July 28th, 1909, and March 18th and 21st, 1910).

No. $\frac{4448}{16}$ Indian Museum Coll.

The antennæ of this species are very variable; in three specimens the second and third antennal joints were equal in length; one example possessed only three joints to the antennæ; and another specimen had three joints to the right antenna and four to the left. These anomalies are most likely to be explained as being due to the results of regeneration after an injury. The specimens were in each case, so far as could be ascertained, quite mature.

Pseudosira indra does not agree fully with the diagnosis of the genus given by Schött. The chief points of difference are: (a) the presence of teeth to the superior claws of the feet; (b) the relative length of the joints of the antennæ; and (c) the great length of the fourth abdominal segment. As Schött erected the genus on a single specimen only, some of his generic characters will, I believe, prove to be of nothing more than specific value.

Börner* separates *Pseudosira* from *Seira* principally by the fact that the dentes are scaled ventrally in the former and not so in the latter genus. This character along with the hook-like mucro renders the genus *Pseudosira* easy of recognition.

Genus SINELLA Brook.

Sinella Brook, "On a new genus of Collembola allied to *Degeeria*," Journ. Linn. Soc., Zool. xvi. 1882, p. 541.

SINELLA MONTANA, sp. n. (Pl. VIII. fig. 48; Pl. IX. figs. 56, 57.)

Ocelli nulli. Unguiculus superior denticulis quattuor armatus. Mucrones furcule dente uno atque seta spiniforme uno instructi. Omnino alba. Long. 2 mm.

Head.—The eyes and post-antennal organs absent.

Antennæ.—Measuring .9 mm. long; the joints related respectively in length as 8 : 13 : 13 : 26; the terminal joint tapering somewhat distally. Clothed with pilose hairs; setæ are present among the hairs on the first three joints, and on the proximal portion of the fourth joint.

Trunk.—Clothed with short pilose (compound) hairs, among which, on the head and mesothorax, are numerous large erect setæ similar to those of *Sinella curviseta* Brook (fig. 57a). The extremity of the abdomen provided with longer compound hairs (fig. 57b). The segments related to one another in length as 15 : 10 : 5 : 11 : 11 : 32 : 7 : 5.

* Das System der Collembolen, pp. 164 and 174.

Legs.—*Superior claws* of the feet elongate and acuminate, with two large slender proximal teeth; in front of the latter are two minute teeth, the distal one extremely small and situated just behind the apex of the claw. The *inferior claws* flattened, bifid at their apex; resembling those of *Sinella höfti* Schöff. (fig. 48). *Tenent hairs* absent, their place being occupied by a slender tapering seta. The legs are clothed with plumose compound hairs similar to those found on the trunk, and among them, on the inferior surface of the tibiæ, are spine-like setæ (fig. 48).

Furcula.—Equal in length to the antennæ; the *manubrium* related in length to the dentes as 2 : 3; clothed on its dorsal aspect with long plumose hairs. The *mucrones* resembling those of *S. höfti*; provided with a single stout and prominently curved terminal tooth, and a basal backwardly directed spiniform tooth (fig. 56).

Coloration.—Entirely white.

Length in adult examples 2 mm.; in young specimens 1-1.5 mm.

Two adult specimens and four young specimens; taken in an ants' nest under stones on a mountain-side near Badrinath, Garhwal Himalaya, circa 10,300 ft. (*A. D. Imms*, May 27th, 1910).

No. $\frac{8606}{16}$ Indian Museum Coll.

This species is closely allied to *Sinella höfti* Schöff., but differs in the claws of the feet. It is readily separable from *S. myrmecophila* Reuter, which similarly occurs in ants' nests, by the characters of the mucro and feet.

The young examples differ from adult specimens chiefly in having the first antennal joint proportionately shorter.

Genus DICRANOCENTROIDES, gen. nov.

Mesonotum non prominens. Segmentum abdominale quartum longius dimidia parte trunci. Antennæ dimidia corporis parte longiores, quadriarticulatæ. Ocelli 16 : 8 in utroque latere capitis. Furcula latitudine apici fere æqualis. Dentes spinosi; mucrones lati denticulis armati. Cutis squamosa.

This genus agrees with *Dicranocentrus* Schött in the dentes being armed with simple spines, and in the length of the antennæ. With *Campylothorax* Schött it agrees in the great length of the fourth abdominal segment, in the form of the furcula, which scarcely tapers in width up to the apex, and in the form of the mucrones. It is separable from the latter genus on account of the thorax not being flexed upon itself, and the relative shortness of the antennæ.

*DICRANOCENTROIDES FASCICULATUS, sp. n. (Pl. VIII. figs. 45-47; Pl. IX. figs. 55 & 55 a; Pl. X. fig. 68.)

Antennæ articulo ultimo omnium longissimo; ceteris inter se

longitudine equalibus. Unguiculus superior duobus dentibus armatus; unguiculus inferior lanceolatus. Mucrones lati denticulis quinque. Long. 2.5-3.5 mm.

Head.—Equal in length to the mesothorax. The eyes eight in number on each side; *post-antennal organs* absent.

Antennæ.—Slightly longer than half the total length of the body (including the head). The first three joints subequal in length, the terminal joint a little longer than the preceding ones. The first two joints clothed with long and conspicuous, erect, almost black setæ; the joints in consequence appearing greatly swollen to the naked eye, and like "bottle brushes" when viewed under the low power of the microscope (fig. 68).

Trunk.—Clothed with both hairs and scales with many transitional structures between the two (fig. 47). The segments related to one another in length as 12 : 5 : 4 : 5 : 5 : 44 : 4 : 2; the fourth abdominal segment longer than half the total length of the trunk.

Legs.—Long, the third pair longest of all and extending to the apex of the abdomen. A single long *tenent hair* in relation with each foot. The *superior claw* of the first and second pairs of legs long, and gradually tapering to a point (fig. 45), armed with two teeth along its inner margin; one tooth situated at a distance from the base of the claw equal to one third of the total length of the claw, the second tooth placed at the same distance from the apex of the claw. The *inferior claw* lanceolate and acuminate, unarmed, but in occasional specimens its inner margin shows minute rudimentary serrations. The superior claw of the third pair of legs slightly broader than that of the preceding pair; the inferior claw with a minute tooth at its base on the inner margin.

Ventral Tube.—Long and cylindrical, the vesicles bilobed (fig. 68).

Furcula.—Reaching to the ventral tube; clothed ventrally with scales. The *dentes* scarcely narrowing to their apices, a little longer than the *manubrium*, armed with a longitudinal row of short stout lanceolate spines along the middle of the inner lateral margin of each (fig. 46). Towards the apex of the dens the spines become replaced by stout setæ. The *mucrones* with two large terminal teeth, two smaller dorsal, sub-apical teeth, and a lateral tooth (fig. 55).

Coloration.—Seen with the naked eye when alive, it appears black with a conspicuous yellow band across the abdomen. It varies from very deep purple-brown to black, with an extremely variable arrangement of the colour-pattern. In the majority of individuals, the base of the metathorax, and the first and second abdominal segments are pale yellow suffused with purplish brown. The first two joints of the antennæ are similar to the ground colour of the body, the third and fourth joints vary from yellow to dark violet. At the base of each joint, in five out of the six specimens, there is a narrow transverse band of pale

yellow. The legs and furcula vary from pale dirty yellow, with purplish or violet suffusions, to deep purple.

Length 2·5–3·5 mm.

Six specimens, taken under damp dead leaves, chiefly of *Quercus*, in forest at Bhowali, Himalayan foot-hills of Kumaon, circa 5700 ft. (A. D. Imms. October 23rd, 1909).

No. $\frac{4394}{16}$ Indian Museum Coll.

Genus CREMASTOCEPHALUS Schött.

Cremastocephalus Schött, "North American Apterygogenea," Proc. Cal. Acad. Sci. 2nd ser. vol. vi. 1896, p. 175.

Cremastocephalus Schäffer, "Collembola des Bismarck-Archipels," Arch. f. Naturgesch., 1898, p. 406.

CREMASTOCEPHALUS INDICUS, sp. n. (Pl. IX. figs. 58, 59.)

Ocelli 16 : 8 in utroque latere capitis. *Unguiculus superior duobus parvis dentibus armatus; unguiculus inferior inermis. Prætarsi pilis clavatis singulis instructi. Mucrones furculæ trilobati. Long.* 1·5 mm.

Head.—The eyes eight in number on each side; the post-antennal organs absent.

Antennæ.—Long and slender, equal to the combined length of the trunk and furcula. The joints related proportionately in length as 5 : 7 : 4 : 7. The two basal joints armed with long slender setæ.

Trunk.—Densely covered with fine hairs and slender setæ. The segments mutually related in length in the proportion of 16 : 7 : 7 : 13 : 1 : 50 : 7 : 2.

Legs.—The superior claws moderately stout, armed with two minute teeth (fig. 58): in 15 per cent. of the specimens one or other of these teeth was absent. The inferior claws broad, obliquely truncated distally, unarmed. A single, very stout, tenent hair to each foot arising from the prætarus.

Furcula.—Reaching to the ventral tube. The manubrium related in length to the dentes in the proportion of 8 : 11. The mucrones (fig. 59) quadrangular, with the distal border trilobed; in some specimens the lobes appeared to be worn down and absent. A single small scale-like appendage at the apex of each dens on the dorsal side.

Coloration.—Ground colour varying from cream colour to yellow. The eyes on a conspicuous black patch on either side of the head. The lateral margins of the thorax and first abdominal segment edged with indigo-blue; a few scattered patches of the same colour over the rest of the abdomen. The antennæ suffused distally with violet; the legs and furcula white.

The coloration, however, is extremely variable, and a detailed description of the various forms that occur would occupy considerable space. In several instances almost all traces of the indigo-blue markings were absent; this reduction of the colour-

pattern is more evident in the Allahabad specimens. On the other hand, in several of the Bengal specimens the markings are much enlarged and intensified.

Length varying from 1 mm. to 1.75 mm.; average length 1.5 mm.

Twenty-five specimens, taken at night crawling up the surface of a whitewashed outer wall of a bungalow, illuminated by electric light, Allahabad (*A. D. Imms*, September 22nd, 1907).

No. $\frac{449}{16}$ Indian Museum Coll.

Twenty-six specimens, taken under dead leaves, Calcutta; for the most part poorly preserved (*Indian Museum Collector*, Jan. 1st, 16th, and 18th, 1908).

CREMASTOCEPHALUS MONTANUS, sp. n. (Pl. IX. fig. 60.)

Ocelli 16 : 8 in *utroque latere capitis*. *Unguiculus superior duobus parvis dentibus armatus; unguiculus inferior inermis. Prætarsi pilis clavatis singulis instructi. Mucrones furculæ tribus dentibus armati. Long.* 2–2.5 mm.

Head.—The *eyes* eight in number on each side; *post-antennal organs* absent.

Antennæ.—The first two joints related proportionately in length as 5 : 7; the remaining joints missing in the specimens examined.

Trunk.—The *segments* related in length in the proportion of 5 : 3 : 3 : 4 : 1 : 15 : 2 : 1. Clothed with fine hairs and slender setæ.

Legs.—The *superior claws* moderately stout, armed with two small teeth; one tooth situated from the base of the claw at a distance equal to one third the length of the claw; the other placed at a similar distance from the apex. The *inferior claws* broad, resembling those of *C. indicus* (fig. 58), only slightly more acuminate; unarmed. A single *tenent hair* to each foot very stout, and arising from the prætarus.

Furcula.—The *mucrones* inclined at an angle of 30° with the *dentes*, tridentate (fig. 60). At the apex of each *dens* is a *scale-like appendage*, equal in length to the mucro.

Coloration.—Straw-coloured inclining to yellow. The lateral margins of the thorax and the first segment of the abdomen edged with dark violet. A few dorso-lateral markings of the same colour over the rest of the abdomen, and a proximal and distal suffusion to each of the tibiæ. The two basal antennal joints inclining to pale yellow; the furcula white.

Length 2–2.5 mm.

Three examples, taken among damp soil under stones and leaves at Kurseong, E. Himalayas, 5000 ft. (*F. H. Gravely*, March 25th, 1910).

No. $\frac{8608}{16}$ Indian Museum Coll.

Cremastocephalus montanus is closely related to the preceding species (*C. indicus*), but can be readily separated by the form of

the mucro. In *C. montanus* the mucro is relatively short, prominently tridentate, and the scale-like appendage is equal in length to that organ. In *C. indicus* the mucro is longer, is not toothed but merely lobed, and the scale-like appendage is considerably shorter.

Genus *PARONELLA* Schött (*sens. lat.*).

Paronella Schött, "Insektenfauna von Kamerun: Collembola," Bihang till K. Sv. Vet.-Akad. Handl., Bd. 19, Afd. iv. p. 14, taf. iv.

Paronella Schäffer, "Die Collembola des Bismarck-Archipels," Arch. f. Naturgesch. 1898, p. 408. (Including *Trichorypha* Schött, *loc. cit.* p. 16, taf. v.)

Schäffer described *Paronella dahliei* from the Bismarck Arch., which is intermediate in its characters between *Paronella* and *Trichorypha*. I have, therefore, followed him by including Schött's two genera in the single genus *Paronella*. Schött states that the ocelli are four in number on each side in *Paronella*, but, nevertheless, figures eight in a group! This latter number obtains in *Paronella dahliei*.

**PARONELLA BÖRNERI*, sp. n. (Pl. X. figs. 70-74; Pl. XI. figs. 75, 76.)

Segmentum abdominale quartum dimidiam trunci partem occupans. Antennæ corpore longiores. Ocelli 16:8 in utroque latere capitis. Unguiculus superior denticulis tribus (vel duobus) instructus; unguiculus inferior inermis. Mucrones lati. Long. 3.5 mm.

Head.—Longer than broad, approximately equal in length to the thorax; inclined at an angle of 45° with the longitudinal axis of the body. A group of strongly chitinated setæ between the eyes and directed forwards towards the bases of the antennæ. The eyes eight in number on each side (fig. 74); *post-antennal organs* absent.

Antennæ.—Very long, the length apparently varying according to age, and sometimes exceeding that of the body and furcula taken together. The first two joints sub-equal in length, the first joint provided with a number of very long slender setæ on its inner and ventral aspects. The third joint a little more than one half the length of the second. The fourth joint long and slender; variable, but usually equal to the combined length of the first two joints; slightly but irregularly annulated, and densely clothed with setose pile. (*Vide* fig. 75.)

Trunk.—Elongate fusiform in shape, straight (fig. 75). The segments related proportionately in length as 7:3:2:4:1:21:2:1, or in other examples as 8:4:3:5:2:21:2:1; the fourth abdominal segment occupying from $\frac{1}{2}$ to $\frac{2\frac{1}{4}}{4\frac{1}{6}}$ of the total length of the trunk. An abundant covering of scales, hairs, and setæ (fig. 73).

The *scales* lanceolate, the hairs finely plumose (compound). Groups of strongly chitinated curved setæ are present along the anterior border of the mesothorax, forming a "frill" or "collar," and at the extremity of the abdomen.

Legs.—Long and slender; the tibiæ divided by means of a movable joint into a longer proximal and a shorter distal segment. The femora of the first pair provided with several extremely elongate slender (sensory?) setæ along their inner aspect (fig. 76). The *superior claws* straight, as long as the width of the distal joint of the tibia at the base (fig. 71); armed with two teeth along the inner margin—one tooth situated at a distance from the base of the claw equal to approximately one third the total length of the latter, the second tooth situated at a similar distance from the apex of the claw. In many examples there is a minute tooth placed between the distal tooth and the apex of the claw. The *inferior claws* straight and acuminate. In relation with each foot is a single stout *tenent hair*, broadly expanded at its apex. *Pseudonychia* long.

Ventral Tube.—Moderately long, cylindrical. The vesicles were retracted in all the specimens examined.

Hamula.—Situated on the anterior third of the fourth abdominal segment. The *corpus* somewhat mammilated, armed with a stout, median backwardly directed *spine*. The *rami* short and stout, each provided with four small teeth (fig. 72).

Furcula.—Long and slender, as long as the trunk-region. The *dentes* parallel-sided or only very slightly tapering towards their apices, clothed with numerous long hairs. The *dentes* related in length to the *manubrium* as 27 : 22. The *mucrones* stout and broad, wedge-shaped in sectional area; armed with two large apical teeth, a lateral inside tooth, and a row of three dorsal teeth (fig. 70). The distal extremity of the mucro armed with a very stout rod-like *seta* on its inner side towards the ventral aspect. At the base of each mucro on the dorsal aspect of the dens is a *scale-like organ** (fig. 70).

Coloration.—The ground colour varying from dirty cream colour to yellow, with indigo or violet-black markings disposed in the following manner:—A lateral area on either side of the head embracing the eye-group; a few small patches at the bases of the antennæ; and irregular lateral markings on each of the thoracic and abdominal segments which, however, are scarcely visible dorsally. On the dorsal aspect of the fourth abdominal segment are a few bilaterally symmetrical markings, and a lateral patch on either side of the fifth segment. The femora marked with a distal band of violet; a small proximal band and a more extensive distal band of the same colour on the first joint of the tibia. A pale violet suffusion on the second (or distal) joint of the latter (fig. 76).

The general colour-pattern, however, is very variable, and for

* Termed by Schäffer "Schuppenförmiger Anhang."

this reason it has only been possible to describe it in a general fashion. The markings on the legs are an exception, being remarkably constant.

Length varying from 2-4.5 mm.; average length 3.5 mm.

Twenty-seven specimens from Nara Ghat, in the Terai, Nepal (*Indian Museum Collector*, February 25th and 26th, 1908); and two immature specimens from Butal, also in the Terai, Nepal, taken by the same collector (February 12th, 1908).

Nos. $\frac{4381}{16}$ and $\frac{4382}{16}$ Indian Museum Coll.

This species shares the characters of the genera *Paronella* and *Campylothorax*. It resembles the latter genus, and differs from typical members of *Paronella* in the great size of the fourth abdominal segment. It is readily separated from *Campylothorax* by the fact that the metathorax is straight and not curved upon itself.

PARONELLA TRAYANCORICA, sp. n. (Pl. IX, figs. 62-66; Pl. X, fig. 67.)

Segmentum abdominale quartum $\frac{2}{5}$ *partem trunci occupans. Antennæ corpore breviores. Ocelli* 16 : 8 *in utroque latere capitis. Unguiculus superior denticulo uno armatus; unguiculus inferior acuminatus, inermis. Mucrones lati, rectangulares. Long.* 3.5-4.5 mm.

Head.—Clothed with scales. The *eyes* eight in number on each side (fig. 64); *post-antennal organs* absent.

Antennæ.—A little shorter than the body. The joints related in length as 7 : 8 : 6 : 15 (fig. 67). The basal joint clothed with setæ and acuminate scales; the distal three-fourths of the terminal joint slightly and irregularly annulated.

Trunk.—Clothed with scales and scattered setæ. The *scales* (fig. 66) linear or linear-oval in shape. A group of strongly chitinised setæ forming a kind of "collar" or "frill" along the anterior border of the mesothorax, and a tuft of similar setæ at the extremity of the abdomen. The *segments* mutually related in length as 10 : 5 : 3 : 5 : 5 : 22 : 4 : 1; the fourth abdominal segment occupying two-fifths the total length of the body (fig. 67).

Legs.—Sub-equal. A single *tenent hair* at the distal extremity of each tibia. The *superior claws* of the feet (figs. 62 and 63) nearly straight, broad at the base; a single minute tooth on the inner margin near the base of the claw. In two specimens, on the first pair of legs, there was present a minute tooth situated in front of the first tooth, and separated from it by a distance equal to one third the total length of the claw. The *inferior claw* lanceolate and acuminate, unarmed. *Pseudonychia* large.

Ventral Tube.—Long, with highly protrusible bilobed vesicles; the anterior lobe of each four times the length of the posterior lobe (fig. 67).

Hamula.—The *corpus* with a stout median anterior seta

situated anterior to the rami. The *rami* armed with four small teeth.

Furcula.—Reaching to the ventral tube; clothed with long setæ (fig. 67). The *mucrones* quadrangular, armed with four terminal teeth and a small lateral tooth on each side (fig. 65).

Coloration.—Purple-brown, somewhat paler in the mid-dorsal region. The head and first joint of the antennæ darker than the rest of the body. The first and second antennal joints with a distal band of cream-colour, the third and fourth joints entirely cream-coloured with a slight purplish suffusion. The basal joints of the legs, together with the femora, purplish brown; the femora with their apices cream-coloured. The tibiæ cream-coloured with a proximal and distal band of purple. The ventral tube suffused with purple. The furcula pallid with light purple suffusions.

Length varying from 3·5–4·5 mm.

Four specimens, taken among dry leaves and stones on the edge of a jungle-stream at Maddathoray, W. base of W. Ghats, Travancore, S. India (*N. Annandale*, November 18th, 1908).

No. $\frac{4388}{16}$ Indian Museum Coll.

* *PARONELLA GRACILIS*, sp. n. (Pl. XI. figs. 77, 78.)

Segmentum abdominale quartum segmentis precedentibus tribus duplo longius. Antennæ corpore longiore. Ocelli 16 : 8 in utroque latere capitis. Unguiculus superior denticulis tribus (vel duobus) instructus; unguiculus inferior inermis. Mucrones lati. Long. 5 mm.

Head.—Considerably longer than broad. The *eyes* eight in number on each side; *post-antennal organs* absent.

Antennæ.—Longer than the body, in some cases as long as the combined length of the body and furcula. In full-grown examples they vary from 6·5–7·5 mm. in length. The relative lengths of the joints varying from the proportion of 15 : 15 : 10 : 27 to 17 : 16 : 10 : 30. Densely clothed with hairs; on the basal joint lanceolate scales are present among the hairs.

Trunk.—Clothed with small lanceolate *scales*, among which are numerous hairs; a “fringe” of setæ along the anterior border of the mesothorax. The segments related proportionately in length as 9 : 6 : 4 : 5 : 2 : 22 : 2 : 1. The fourth abdominal segment double the length of the three preceding segments.

Legs.—Long and slender, clothed with slender, elongate setæ. The tibiæ divided by a joint into proximal and distal portions, related respectively in length in the proportion of 2 : 1. A single long stout *tenent hair* in relation with each foot. The *superior claws* moderately slender, straight (fig. 77); armed with two teeth, one placed at a distance from the base equal to one-third the total length of the claw, the other placed at a similar distance from the apex. Between the distal tooth and the apex of the claw is a minute tooth which, however, is not always present.

The *inferior claws* markedly acuminate, unarmed. *Pseudonychia* large, projecting laterally.

Ventral Tube.—1.75 mm. long, slender, cylindrical. The vesicles each subdivided into a long anterior lobe and a shorter posterior lobe.

Furcula.—Reaching to the ventral tube; average length 2.25 mm. The *dentēs* slightly tapering towards their extremities; related in length to the manubrium in the proportion of 7 : 5. The *mucrones* (fig. 78) complex, wedge-shaped when viewed in section; armed with a prominent terminal tooth, and a small ventral tooth applied to the base of the latter; two lateral teeth on the inner side of the mucro. The dorsal edge of the mucro provided with four teeth. The apex of the dens provided with a *scale-like organ* on the dorsal side, and a stout rod-like *seta* on its inner aspect.

Coloration.—The ground colour varying from cream to pale yellow, darkening according to the number of scales present. The eyes on a black patch on each side of the head. The antennæ a little darker than the ground colour of the body, inclining in some examples to pale brown; the basal joint longitudinally streaked with violet-black. Body-markings varying from violet-black to almost black, giving the insect a mottled appearance to the naked eye. The sides of the head and the lateral margins of the thorax and first abdominal segment violet-black. A few lateral markings of the same colour on the remaining abdominal segments. The only dorsal marking is a narrow irregular transverse streak crossing the head behind the bases of the antennæ. The femora marked with a distal band of violet; the proximal tibial joint with both proximal and distal bands of the same colour; the distal tibial joint with a violet suffusion across the middle.

In very pale examples the body-markings are entirely absent, only the legs retaining the usual coloration. In very dark specimens the markings along the sides of the trunk are confluent, and are united by transverse bands crossing the two thoracic segments, and each of the first three segments of the abdomen.

Length varying from 5–5.5 mm.

Twenty-two examples, taken among damp dead leaves in forest of rhododendron and oak at Bhowali, Himalayan foot-hills of Kumaon, 5700 ft. (A. D. Imms, October 18th–23rd, 1909).

No. ⁴³³⁰/₁₆ Indian Museum Coll.

* *PARONELLA PHANOLEPIS*, sp. n. (Pl. X. fig. 69; Pl. XI. fig. 79.)

Unguiculus superior duobus parvis dentibus armatus; unguiculus inferior lanceolatus, inermis. Mucrones lati, quattuor apicalibus et tribus dorsalibus denticulis armati. Denticuli dorsales ita collocati ut unus post alterum insertus sit. Articulus quartus

antennarum secundo et tertio longitudine æquus, vel paullo longior. Setæ corporis longæ, in fasciis instructæ. Long. 3·5 mm.

Head.—Invested with scales and provided with a prominent dorsal tuft of large sub-erect setæ. The eyes eight in number on each side; no *post-antennal organs*.

Antennæ.—Varying in length from 4 to 4·5 mm.; the joints very variable in length. The first two joints sub-equal; the fourth joint at least as long as the combined length of the second and third joints. The exact numerical proportions in the length of the antennal joints of four typical specimens were 50 : 50 : 32 : 89; 55 : 54 : 37 : 95; 53 : 54 : 34 : 88; and 51 : 51 : 35 : 86. The two proximal joints clothed with scales and hairs, the distal joints entirely clothed with hairs of various lengths.

Trunk.—The segments related proportionately in length as 14 : 9 : 6 : 11 : 6 : 37 : 5 : 2. Clothed with small lanceolate scales densely packed together; in the mid-dorsal line the scales are considerably larger and oblong-ovate in shape. A prominent investiture of large and very conspicuous sub-erect setæ with curved extremities disposed in the following manner:—A "collar" along the anterior margin of the mesothorax, a few scattered setæ of similar type on the dorsal aspect of the segment and a group near the posterior border. Similar groups are situated near the posterior margins of the metathorax and the first two abdominal segments. The third abdominal segment with a few scattered setæ only. The fourth abdominal segment with a conspicuous tuft of longer and more slender setæ about the middle of its dorsal aspect, and a fringe of similar setæ, directed backwards, along its posterior and postero-lateral margins. The fifth and sixth abdominal segments densely clothed with setæ and partially concealed by them.

Legs.—The femora and basal joints scaled. The tibiæ distinctly separated into proximal and distal joints; the former related in length to the latter as 19 : 7 on the third pair of legs, and as 17 : 7 on the first pair of legs; clothed with hairs and setæ of various lengths. The *superior claws* of the feet lanceolate and acuminate, armed with two small teeth (fig. 69); one tooth situated at a distance from the base of the claw equal to one third the total length of the latter, the second tooth situated at a similar distance from the apex of the claw. The *inferior claws* lanceolate and acuminate, unarmed. *Pseudonychia* large, at least one half the length of the inferior claw. A single stout *tenent hair* to each foot.

Furcula.—In length varying from 2·5 to 2·75 mm.; the ratio of the length of the manubrium to that of the *dens* varying from 11 : 12 to 3 : 4; in the majority of examples, however, the ratio is as 4 : 5. The *mucro* large and somewhat plate-like; armed with an outer and inner apical tooth, each provided with a slender lateral tooth prolonged down the mucro in the form of a ridge. The inner apical tooth is continuous at its base with the dorsal plate-like portion of the mucro. The latter bears two large

backwardly directed teeth, situated just behind the inner apical tooth, and a small acicular tooth near to the base of the mucro. At the apex of the dens, on its inner aspect, is a small *scale-like organ* (fig. 79).

Coloration.—Colour when alive leaden purple (in some specimens almost black) with a slight metallic sheen. The antennæ and legs purple-black. The furcula greyish white. In alcohol specimens the colour is purple-black when but few of the scales have been lost. In the majority of cases the specimens become denuded of a large proportion of the scales, and the body-colour then appears mottled and streaked with shades of brown and purple-black.

Length varying from 3–3·75 mm.

Thirteen examples, taken on the inside walls of an old bungalow, probably residing in decaying beams and rafters; Bhowali, Himalayan foot-hills of Kumaon, *circa* 5700 ft. (A. D. Imms, June 12th–29th, 1910).

No. $\frac{8607}{16}$ Indian Museum Coll.

Perfect examples of this species are easily recognised by the conspicuous tufts of sub-erect setæ; in alcohol specimens the latter fall off with extreme readiness and are usually absent.

In five of the specimens the two distal antennal joints are lemon-yellow, and very conspicuous in consequence. Whether this is a sexual or varietal difference I am unable to say.

* PARONELLA INSIGNIS, sp. n. (Pl. XI. fig. 80; Pl. XII. figs. 81 & 82.)

Unguiculus superior uno dente armatus; unguiculus inferior aculeatus, inermis. Mucrones lati, duobus denticulis apicalibus et tribus denticulis dorsalibus armati. Denticuli dorsales ita collocati ut unus post alterum sit insertus. Long. 3·7 mm.

Head.—A little longer than the mesothorax; covered with scales, among which are a few scattered setæ. The *eyes* eight in number on either side; *post-antennal organs* absent.

Antennæ.—Very long and slender, exceeding 5 mm. in length. The joints mutually related in length in the proportion of 17 : 13 : 23.

Trunk.—Elongate, linear, clothed with scales. The *scales* small and broadly lanceolate; a tuft of *setæ* at the extremity of the abdomen. The *segments* related in length as 10 : 8 : 5 : 6 : 5 : 22 : 3 : 2 (fig. 80).

Legs.—All the legs similar; the tibiæ distinctly divided into proximal and distal portions by a definite joint. The proximal portion a little more than twice the length of the distal portion (*i. e.*, as 15 : 7). The *superior claws* (fig. 81) of the feet slender and tolerably long, armed with a single tooth situated at a distance from the apex of the claw equal to one third the length of the claw. In some examples there is also a rudimentary tooth placed at a similar distance from the base of the claw.

The *inferior claws* nearly as long as the superior claws, unarmed; their distal portion abruptly narrowed, becoming acicular. A single long stout *tenent hair* in relation to each foot.

Ventral Tube.—Long and cylindrical, emitting a pair of elongate vesicles, each of the latter subdivided into a longer and shorter lobe (fig. 80).

Furcula.—As long as the abdomen; the *manubrium* related in length to the *dens* as 10 : 13. The *muero* (fig. 82) broad and flattened, inclined at an obtuse angle with the long axis of the dens; armed with an outer and inner terminal tooth and a row of three sharply pointed teeth along its dorsal edge, situated one behind the other. The apex of the dens provided with stout elongate setæ slightly longer than the *muero* (fig. 82).

Coloration.—The ground colour varying from light yellow to brown-yellow with markings of brownish purple. The antennæ purplish; the posterior half of the head, together with the lateral and anterior margins of the mesothorax, and the first three abdominal segments, suffused with brownish purple. The fourth abdominal segment suffused with the same colour along its sides, and along its anterior and posterior margins. A broad transverse band of similar colour crosses the middle of the segment, but is interrupted in the mid-dorsal line. The eyes on a black patch on each side of the head. The furcula and ventral tube yellowish white. The legs with the tibial joints almost entirely dark purple except for a whitish suffusion at the apex of their distal joint. The femora suffused with purple, especially towards their apices.

Length. Average length measures 3·7 mm.

Five examples, taken from among dry leaves and stones along the edge of a jungle-stream at Maddathoray, W. base of W. Ghats, Travancore, S. India (*N. Annandale*, November 18th, 1908).

No. $\frac{8610}{16}$ Indian Museum Coll.

In none of the five specimens were the antennæ perfect, except in the case of the example figured on Pl. VI. The number of joints (3) is exceptional among Collembola, and it is unlikely that the antenna has been injured and has not regenerated the full number of joints (4). Such examples are known to be not infrequent in *Tomocerus*, *Orchesella*, and other genera.

Genus IDIOMERUS, gen. nov.

Mesonotum prominens, conicus. Ocelli 16 : 8 in utroque latere capitis; organa postantennalia carent. Antennæ quinque-articulatæ; articulis basalis perparvus, ultimus longissimus. Cutis squamosa.

This genus is easily recognisable by the remarkable form of the mesonotum, which projects upwards in the form of a cone above the level of the rest of the body (text-fig. 15).

* *IDIOMERUS PALLIDUS*, sp. n. (Pl. IX. fig. 61.)

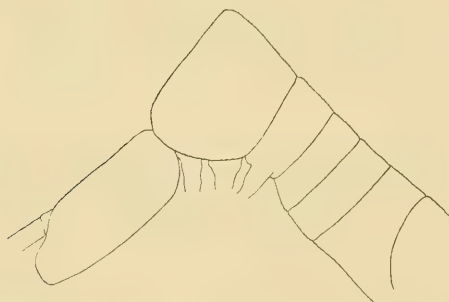
Segmentum abdominale quartum fere dimidium partem trunci occupans. Unguiculus superior duobus parvis dentibus armatus; unguiculus inferior lanceolatus, inermis. Mucrones lati. Long. 3.5-5 mm.

Head.—Longer than broad, equal to the combined length of the metathorax and first three abdominal segments; clothed with scales. The *eyes* eight in number on each side; the *post-antennal organs* absent.

Antennae.—Five-jointed, a little longer than the body. The basal joint small, and concealed (text-fig. 15); the terminal joint the largest, variable in length. The relative lengths of the joints are as 1 : 24 : 21 : 17 : 32.

Trunk.—Clothed with scales; a "collar" of long setae along the anterior margin of the mesothorax, and a tuft at the extremity of the abdomen. The segments related to one another in length in the proportion of 16 : 6 : 4 : 5 : 4 : 36 : 4 : 1. The fourth abdominal segment occupying a little less than half the length of the trunk, equal to the total length of the preceding trunk-segments.

Text-fig. 15.



Outline figure of *Idiomerus pallidus*, showing the characteristic shape of the mesonotum.

Legs.—The legs sub-equal; a single *tenent hair* at the apex of each tibia. The *superior claws* moderately slender, acuminate, armed with two minute teeth, inserted one behind the other on the inner margin. The *inferior claws* lanceolate and acuminate, unarmed. The *pseudonychia* large. The *tibiae* biarticulate, the proximal and distal portions related to one another in length in the proportion of 15 : 7.

Ventral Tube.—Long and cylindrical.

Hamula.—Closely resembling that of *Paronella börneri* (Pl. X. fig. 72); the *corpus* carrying a stout median seta between and in front of the *rami*. The *rami* each armed with four small teeth.

Furcula.—Reaching to the ventral tube, clothed ventrally with lanceolate scales. The *dentes* only slightly tapering distally; the

manubrium related in length to the dentes in the proportion of 26 : 29. The *mucrones* broad (fig. 61), armed with three large rounded terminal teeth, a lateral tooth on the outer side, and an erect dorsal tooth with a spiniform tooth at its base.

Coloration.—The ground colour varying from a dirty cream-colour to light yellow, with the furcula and ventral tube paler. A few small purple-black markings on the head between the eyes, and around the bases of the antennæ. A longitudinal stripe of the same colour along the greater part of the length of the last pair of femora. In two specimens the other femora were similarly streaked. The eyes on a black patch on either side of the head.

In specimens retaining their full complement of scales the ground colour appears darker and inclined to a brownish tinge.

Length varying from 3.5–5 mm.

Five examples, taken among dry leaves and stones along the edge of a jungle-stream at Maddathoray, W. base of W. Ghats, Travancore, S. India (*N. Annandale*, November 18th, 1908).

No. $\frac{4387}{16}$ Indian Museum Coll.

In one example out of the five the upper claw of the feet was devoid of teeth, and in a second specimen there was only a single tooth present. The *mucrones*, however, supply much more constant specific characters.

Genus CYPHODERUS Nicolet,

Cyphodeirus Nicolet, Rech. pour serv. à l'hist. des Podur., Neuchâtel, 1841, p. 63 (*ad partem*).

Cyphoderus Tullberg, "Fört. öfver Sv. Podur.", Öfvers, Kongl. Vet.-Akad. Förhandl. xxvii. 1871, p. 150.

CYPHODERUS SIMULANS, sp. n. (Pl. XII. figs. 90, 91.)

Omnino albus. Ocelli nulli. Unguiculus superior uno magno et duobus parvis dentibus instructus. Long. 1 mm.

Head.—The *eyes* and *post-antennal organs* absent.

Antennæ.—Four-jointed, the joints related respectively in length as 2 : 7 : 3 : 10; the terminal joint slender and tapering distally. The length of the antenna is approximately half the total length of the thorax and abdomen.

Trunk.—Closely resembling *C. albinus* Nic.

Legs.—All similar. The *superior claw* long, provided with a very large basal tooth and two small distal teeth; the *inferior claw* bidentate at the apex, the ventral tooth being considerably shorter than the dorsal; a single very slightly curved *tenent hair* (fig. 90).

Furcula.—In length slightly exceeding the antennæ. The *mucrones* (fig. 91) very long and slender, and when viewed dorsally, quite straight; the terminal and dorsal teeth similar to those of *C. albinus*. The *manubrium* and *dentes* clothed ventrally

with scales; the dentes provided with a double row of six large scales, which are somewhat spear-shaped with a prominent mid-rib; to the inner side of each mucro is a large terminal scale (fig. 91).

Coloration.—When alive, white (*Annandale*); in alcohol, pale dirty cream-colour.

Length 1 mm.

Four specimens on bats' dung in total darkness in the Khayon Caves near Moulmein, Burma (*N. Annandale*, March 7th, 1908).

No. $\frac{4446}{16}$ Indian Museum Coll.

The absence of eyes and pigmentation are characteristics of a true cave-dwelling animal. Dr. Annandale informs me, however, that the Khayon Caves are of no great extent, though their inner parts are quite dark.

Cyphoderus simulans is readily distinguished from *C. albinus* Nic.† in possessing a somewhat longer superior claw to the feet, with two small additional teeth. The latter, however, are difficult to detect on account of their delicacy and transparency.

Genus PSEUDOCYPHODERUS, gen. nov.

Mesonotum non prominens. Segmentum abdominis quartum quintuplo longius quam tertium. Antennae dimidiam partem corporis aequantes, infra caput insertae. Mucrones minuti. Manubrium biarticulatum. Ocelli et organa postantennalia carent. Squamis et setis instructus.

This genus may be readily separated from *Cyphoderus* Nic., and *Cyphoderodes* Silvestri‡, by the fact that the mouth and frontal region of the head are completely ventral in position, and consequently, the points of insertion of the antennae are situated on the ventral aspect of the head.

*PSEUDOCYPHODERUS ANNANDALEI, sp. n. (Pl. XII. figs. 87–89.)

Antennae articulis tribus ultimis inter se longitudine sub-aequalibus. Unguiculus superior quadridentatus; unguiculus inferior bifidus. Dentes dimidiam partem manubrii aequantes; quinque squamis externis, tribus internis, et una squama terminali instructi. Mucrones quadridentati, dentes ita collocati ut unus post alterum insertus sit. Long. 1 mm.

Head.—Considerably broader than long, the facial region, together with the mouth, almost entirely ventral in position. The eyes and post-antennal organs absent.

Antennae.—Arising from the ventral surface of the head, four-jointed, the joints related to one another in length as 6 : 14 : 14 : 13.

Trunk.—Densely covered with small scales, among which are some short scattered hairs of variable length. The head and trunk segments related respectively in length as 15 : 12 : 7 : 4 : 4 :

† *Vide* Börner, "Zur Kenntnis der Apterygoten-Fauna von Bremen und der Nachbardistrikte," Abh. Nat. Ver. Bremen, Bd. xvii. p. 71, fig. 28.

‡ In "Termitenleben auf Ceylon," von K. Escherich, Jena 1911, p. 244.

5:26:2:2. The fourth abdominal segment at least five times as long as the preceding segment.

Legs.—Provided with short straight setæ. The *superior claw* of the third pair of legs stout and thick, except at the apex where it becomes swollen and membranous (fig. 87); one large acicular tooth situated at the middle of the inner margin, a minute tooth immediately in front of the former, and a small tooth close to the apex of the claw on either side. The *inferior claw* wide and plate-like, bifid. The claws of the first and second pairs of legs smaller and somewhat shorter. A single *tenent hair* in relation to each foot.

Furcula.—Moderate in size, stout, .4 mm. long, scaled ventrally. When closed up beneath the abdomen the mucrons reach to the anterior border of the fourth abdominal segment. The *manubrium* divided imperfectly into proximal and distal portions (fig. 88). The *dentes* just about half the length of the manubrium, short and stout; each provided along its outer aspect with a dorsal row of five very large scales, a row of two similar scales along the inner side, and a small terminal scale just beneath the mucro (figs. 88 and 89). The proximal inner scale equal in length to the proximal outer scale; the outer and inner apical scales longest of all, the inner slightly longer than the outer. The *mucro* very small and armed with four teeth (fig. 89); a very small terminal tooth, and three dorsal teeth situated one behind the other; the posterior and middle teeth of the row curved and pointed, the anterior (or proximal) tooth blunt and rounded.

Coloration.—In alcohol, white.

Length 1-1.15 mm.

Twelve specimens taken from a nest of Termites at Rhamba, south end of Lake Chilka, N.E. Madras (*N. Annandale*, March 3rd, 1910). The Termite has been subsequently identified by Prof. Silvestri as *Termes redemanni* Wasm.

No. $\frac{4447}{16}$ Indian Museum Coll.

Sub-order SYMPHYPLEONA Börn.

Fam. SMINTHURIDÆ Lbk.

Sub-fam. SMINTHURIDINÆ Börn.

Genus SMINTHURIDES Börn.

† *Sminthurus* (*Smynthurus*) Latreille, Hist. Nat. 1804, T. viii. p. 79 (*ad partem*).

Sminthurides Börner, "Zur Kennt. der Apteryg.-Fauna von Bremen," Abh. Nat. Ver. Bremen, 1901, Bd. xvii. p. 91.

* SMINTHURIDES APPENDICULATUS, sp. n. (Pl. XII. figs. 83-86.)

Articulus ultimus antennarum longissimus, vix annulatus. Pili clavati in tibiis nulli. Unguiculi superiores inermes; unguiculi inferiores in setam longam prolongati. Unguiculi inferiores

pedum posteriorum etiam tribus appendicibus filiformibus instructi. Mucrones furculæ lati, laminati. Long. .5-75 mm.

Antennæ.—Slender, the joints related to one another in length as 8:11:22:32; the terminal joint only with slight indications of annulation (fig. 83).

Trunk.—The abdomen provided dorsally with a few short, curved, scattered hairs.

Legs.—The first and second pairs similar (fig. 85); the *superior claws* very long, at least two and a half times as long as the breadth of the tibia, slightly curved at their apices, unarmed. The *inferior claw* approximately one fifth longer than the superior claw, setiform and whip-like, usually with a minute tooth on its ventral aspect towards the base. The *superior claws* of the third pair of legs shorter and smaller than those of the preceding pairs; the *inferior claws* whip-like, armed at about the middle of their length with a group of three filiform dorsal appendages, and a small tooth situated close to the latter on the ventral surface (fig. 84). No *tenent hairs* to the feet. The tibiæ of the third pair of legs provided with three apical *sense organs* (?) on the inner side (fig. 84).

Ventral Tube.—Very short, without elongate vesicles.

Furcula.—The *dentes*, without their mucrones, equal in length to the abdomen; slightly curved ventralwards. The *mucrones* very large (fig. 86), at least as wide as the maximum width of the dens, lamellate.

Coloration.—Ground colour leaden, the legs and spring paler. The eyes on a black patch on each side of the head. The antennæ dark leaden coloured with a purplish suffusion. A pale yellow dorsal area on the head, bearing a small bluish-purple patch between the eyes. The trunk indigo-blue dorsally, with small pale yellow markings.

Length varying from .5-75 mm.

Twenty-one specimens taken on the surface of water at Calcutta (*Indian Museum Collector*, January 9th, 21st, and 22nd, 1908).

Nos. $\frac{4391}{16}$ and $\frac{4392}{16}$ Indian Museum Coll.

III. A CATALOGUE OF THE ORIENTAL COLLEMBOLA.

In defining the area comprised within the Oriental region, I have followed Blanford * in taking for its northern boundary the limits of forest growth in the Himalayas; while as regards the south-eastern boundary, I have followed the later views that are well summarised by Pelseneer † and supported by the results of the "Siboga" expedition. Pelseneer proposes the name of "Weber's Line" for the south-eastern boundary, which is regarded as passing east of Timor and through the Banda and Molucca Seas.

* "The Distribution of Vertebrate Animals in India, Ceylon, and Burma." *Phil. Trans. Roy. Soc.* vol. 194, 1901, p. 347.

† "La Ligne de Weber, Limite Zoologique de l'Asie et de l'Australie." *Bull. Belg. Acad.* 1904.

With the small amount of knowledge of Oriental Collembola at one's disposal it is impossible to make any generalisations. Two features, however, stand out as notable:—(1) The paucity of the members of the Sub-order Symphypleona, which is represented by only three genera, and as many species, out of a total of fifty-three species of Oriental Collembola. (2) The relative preponderance among species of the genus *Paronella*.

Sub-order ARTHROPLEONA Börn.

Fam. PODURIDÆ Lbk.

Sub-fam. HYPOGASTRURINÆ Börn.

1. *Xenylla obscura*, sp. n. India (W. Himalayas).

Sub-fam. ACHORUTINÆ Börn.

2. *Protanura kræpelini* Börn. Java. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 169.)
3. *Oudemansia cærulea* Schött. Thousand Islands. (Schött; Ent. Tidskr. 1893, p. 172.)
4. *Achorutes lipaspis* Börn. Java. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 170.)
5. *A. hirtellus* Börn. Java. (Börner; *loc. cit.* p. 170.)
6. *A. armatus* Nic. Sumatra. (Oudemans; Zool. Ergeb. einer Reise in Niederl.-Ostind., Hft. i. p. 89.) Ceylon.
7. *A. crassus* Oud. Sumatra. (Oudemans; *loc. cit.* p. 90.)
8. *Ceratameria* (*Schöttella*) *maxima* Schött. Java. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 167.)

Sub-fam. NEANURINÆ Börn.

9. *Pseudachorutes anomalus*, sp. n. India. (E. Himalayas.)
10. *Neanura corallina*, sp. n. Ceylon.
11. *N. pudibunda*, sp. n. Lower Burma.
12. *N. intermedia*, sp. n. India (W. Himalayas).
13. *N. fortis* Oud. Java, Sumatra, and Saleyer. (Oudemans; Zool. Ergeb. einer Reise in Niederl.-Ostind., Hft. i. p. 91.)

Sub-fam. ONYCHIURINÆ Börn.

14. *Onychiurus* (*Lipura*) *finetarius* Burm. Sumatra. (Oudemans; *loc. cit.* p. 90.)

Fam. ENTOMOBRYIDÆ D. T.

Sub-fam. ISOTOMINÆ Schöff.

15. *Isotoma crassicornis* Schött. Sumatra. (Schött; Ent. Tidskr. 1893, p. 172.)
16. *I. nigropunctata*, sp. n. India (E. Himalayas).

Sub-fam. TOMOCERINÆ Schöff.

17. *Tomocerus (Macrotoma) montanus* Oud. Sumatra. (Oudemans; Zool. Ergeb. einer Reise in Niederl.-Ostind., Hft. i. p. 91.)

Sub-fam. HETEROMURICINÆ, sub-fam. nov.

18. *Heteromuricus cercifer*, gen. et sp. n. India (Bengal).

Sub-fam. ENTOMOBRYINÆ Schöff.

19. *Isotomurus (Isotoma) palustris* Müll., India (Bengal). Sub-sp. *tricuspis* Börn. Java. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 173.)
20. *Lepidocyrtus robustus*, sp. n. India (Travancore).
21. *L. braueri* Börn. Seychelles. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 176.)
22. *L. javanus* Börn. Java. (Börner; loc. cit. p. 176.)
23. *L. variabilis* Oud. Sumatra and Java. (Oudemans; Zool. Ergeb. einer Reise in Niederl.-Ostind., Hft. i. p. 84.)
24. *L. javanicus* Oud. Java. (Oudemans; loc. cit. p. 85.)
25. *Entomobrya kali*, sp. n. India (Bengal). Var *lutea* nov. India (W. Himalayas).
26. *E. florensis* Oud. Flores. (Oudemans; loc. cit. p. 86.)
27. *E. longicornis* Oud. Sumatra and Java. (Oudemans; loc. cit. p. 87.)
28. *Seira (Sira) annulicornis* Oud. Java. (Oudemans; loc. cit. p. 87.)
29. *S. sumatrana* Oud. Sumatra. (Oudemans; loc. cit. p. 88.)
30. *S. brahma*, sp. n. India (United Provinces).
31. *Pseudosira indra*, sp. n. India (Bengal).
32. *Dicranocentroides fasciculatus*, gen. et sp. n. India (W. Himalayas).
33. *Heteromurus tenuicornis* Börn. Java. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 177.)
34. *H. tetracantha* Börn. Java. (Börner; loc. cit. p. 177.)
35. *H. (Templetonia)* sp. ? Java. (Oudemans; Zool. Ergeb. einer Reise in Niederl.-Ostind., Hft. i. p. 89.)
36. *Cremastocephalus celebensis* Schäf. Celebes. (Schäffer; Archiv f. Naturges., 1898, p. 407.)
37. *C. montanus*, sp. n. India (E. Himalayas).
38. *C. indicus*, sp. n. India (United Provinces and Bengal).
39. *Paronella tarsata* Börn. Java. (Börner; Mitt. Naturhist. Mus. Hamburg, 1906, xxiii. p. 177.)
40. *P. setigera* Börn. Java. (Börner; loc. cit. p. 178.)
41. *P. börneri*, sp. n. Nepal.
42. *P. travancorica*, sp. n. India (Travancore).
43. *P. gracilis*, sp. n. India (W. Himalayas).
44. *P. phanolepis*, sp. n. India (W. Himalayas).
45. *P. insignis*, sp. n. India (Travancore).

46. *Idiomerus pallidus*, gen. et sp. n. India (Travancore).
47. *Cyphoderus simulans*, sp. n. Burma.
48. *C. javanus* Börn. Java. (Börner; *loc. cit.* p. 180.)
49. *Pseudocyphoderus annandalei*, gen. et sp. n. India (N.E. Madras).
50. *Cyphoderodes ceylonicus* Silv. Ceylon. (Silvestri; in *Termit. auf Ceylon* von E. Escherich, 1911, p. 245.)

Sub-order SYMPHYPLEONA Börn.

Fam. SMINTHURIDÆ Lbk.

Sub-fam. SMINTHURIDINÆ Börn.

51. *Sminthurides appendiculatus*, sp. n. India (Bengal).

Sub-fam. CORYNEPHORINÆ Abs.

52. *Corynephoria jacobsoni* Abs. Java. (Absolon; *Entom. Ztg.* Wien, 26, 1907, p. 338.)

Sub-fam. DICYRTOMINÆ Börn.

53. *Ptenothrix gracilicornis* Schöff., subsp. *gibbosa* Börn. Java. (Börner; *Mitt. Naturhist. Mus. Hamburg*, 1906, xxiii. p. 185.)

IV. A SUMMARY OF GENERAL CONCLUSIONS.

1. Four genera and twenty-seven species of Collembola are described as new, and three species belonging to as many genera were already known. Out of a total of thirty-one species, five are Palearctic, and were obtained above the limits of forest-growth in the Himalayas. The remaining species are Oriental.

2. The Palearctic species are all referable to well-known genera, and were not met with in the Oriental region.

3. Among the Oriental species it has been found necessary to erect four new genera, i. e.:—*Idiomerus*, *Dicranocentroides*, *Heteromuricus*, and *Pseudocyphoderus*. The remaining species all pertain to genera whose range extends into at least one other zoo-geographical region.

4. Among the new forms discovered, the most remarkable is *Heteromuricus cercifer*, gen. et sp. n. It is unique among Collembola in possessing a median cercus to the fifth abdominal segment. A new sub-family—the *Heteromuricinæ*—is proposed for its reception. *Pseudocyphoderus* gen. nov., with a single species, is described from the neighbourhood of Lake Chilka, where it occurs in Termites' nests.

5. The total number of Collembola known from the Oriental region amounts to fifty-three species comprised within twenty-seven genera. Of these only three genera, each with a single species, are members of the sub-order Symphypleona.

V. EXPLANATION OF THE PLATES.

The figures were made with a Leitz drawing apparatus under various magnifications. Wherever arrows are represented they indicate the direction of the anterior end of the body.

PLATE VI.

Pseudachorutes anomalus, sp. n.

- Fig. 1. The right mucro viewed from the lateral aspect.
 2. The eyes and post-antennal organ of the right side.
 3. The right foot of the first pair of legs.
 4. An outline figure of the furcula seen from the dorsal side.

Xenylla obscura, sp. n.

- Fig. 5. An outline figure of the dorsal aspect of the furcula.
 6. A dorso-lateral view of the anal spines and their papillæ.
 7. The mucro and apical portion of the dens of the left side viewed from the inner aspect.
 8. The hamula.
 9. The right leg of the first pair.

Neanura pudibunda, sp. n.

- Fig. 10. The antenna, eyes, and post-antennal organ of the left side.
 11. The left foot of the third pair of legs.
 12. The insect viewed from the dorsal side.

Neanura intermedia, sp. n.

- Fig. 13. The left antenna seen from the dorsal aspect.
 14. The left foot of the first pair of legs.

Isotomurus palustris Müll.

- Fig. 15. The mucro, together with the apex of the dens; right side.

Isotoma siva, sp. n.

- Fig. 16. The left foot of the first pair of legs.
 17. The mucro and apex of the dens of the left side; viewed from the outer side.
 18. The eyes of the right side.

PLATE VII.

Isotoma siva (continued).

- Fig. 19. The insect seen from above.

Neanura intermedia (continued).

- Fig. 20. The eyes of the left side.

Isotomurus palustris (continued).

- Fig. 21. The right foot of the first pair of legs seen from the inner side.
 22. The eyes and post-antennal organ of the right side.

Neanura corallina, sp. n.

- Fig. 23. The insect viewed from above.
 24. The left antenna seen from the ventral aspect.
 25. The eyes of the left side.
 26. The third leg, left side.

Isotoma nigropunctata, sp. n.

- Fig. 27. The eyes and post-antennal organ of the right side.
 28. The right foot of the third pair of legs seen from the inner aspect.
 29. The apex of the dens of the right side together with the mucro.

Entomobrya crassa, sp. n.

- Fig. 30. The mucro and distal portion of the dens of the right side.
 31. The eyes of the right side.

Pseudosira indra, sp. n.

- Fig. 32. The left mucro together with the apical portion of the dens, viewed from the inside.

Entomobrya kali, sp. n.

- Fig. 33. The right foot and apex of tibia of the third pair of legs; inside view.

PLATE VIII.

Entomobrya kali (continued).

- Fig. 34. The insect viewed from above. (The specimen figured has lost the longer setae from the body.)
 35. The left mucro and apical portion of the dens; inside view.
 36. Typical setae from the mesothorax.

Pseudosira indra (continued).

- Fig. 37. The eyes of the right side.
 38. The right foot of the third pair of legs.
 39. A typical seta from the anterior margin of the mesothorax.
 40. A typical body-scale.

Seira frigida, sp. n.

- Fig. 41. The left foot of the third pair of legs.
 42. The mucro and apex of the dens of the left side; inside view.

Seira brahma, sp. n.

- Fig. 43. The left foot of the third pair of legs.
 44. The left mucro and apical portion of the dens; viewed from the inside.

Dicranocentroides fasciculatus, gen. et sp. n.

- Fig. 45. The right foot of the first pair of legs.
 46. A portion of the inner aspect of the dens showing the characteristic spines.
 47. Hairs from various regions of the body. (a) From the apical joint of the antenna. (b) From the tuft on the second antennal joint. (c) An acuminate hair from the legs.

Sinella montana, sp. n.

- Fig. 48. The right foot and apex of the tibia; third pair of legs. *Sp.*, Spine-like setae.

Heteromuricus cercifer, gen. et sp. n.

- Fig. 49. The right foot of the third pair of legs.
 50. The cercus viewed laterally.
 51. One of the larger body-scales.

PLATE IX.

Heteromuricus cercifer (continued).

- Fig. 52. The insect viewed from the right side. (The head is inclined at a greater angle with the trunk than is represented.)
 53. The eyes of the right side.
 54. The left mucro viewed from the outer aspect.

Dicranocentroides fasciculatus (continued).

- Fig. 55. The left mucro viewed from the outer side. *d.*, dens; *l.t.*, lateral tooth.
 55 a. Body-scales.

Sinella montana (continued).

Fig. 56. The right mucro seen from the outside.

57. (a) A seta from the mesothorax. (b) A seta from the extremity of the abdomen.

Cremastocephalus indicus, sp. n.

Fig. 58. The right foot of the third pair of legs.

59. The apex of the dens with the mucro of the left side; inner aspect.

Cremastocephalus montanus, sp. n.

Fig. 60. The apex of the dens with the mucro of the left side; inner aspect.

Idiomerus pallidus, gen. et sp. n.

Fig. 61. The right mucro viewed from the outer side.

Paronella travancorica, sp. n.Fig. 62. The left foot of the second pair of legs; inside view. *ps.*, pseudonychium; *t.h.*, tenent hair.63. The left foot of the second pair of legs viewed from above. *ps.*, pseudonychium; *t.h.*, tenent hair.

64. The eyes of the right side.

65. The left mucro seen from its outer aspect.

66. Body-scales.

PLATE X.

Paronella travancorica (continued).

Fig. 67. The insect seen from the right side.

Dicranocentroides fasciculatus (continued).

Fig. 68. The insect seen from the right side. (The legs have been drawn too short, the hind pair should reach almost to the extremity of the abdomen.)

Paronella phanolepis, sp. n.

Fig. 69. The left foot of the first pair of legs.

Paronella börneri, sp. n.Fig. 70. The mucro and apex of the dens viewed from the outer side; right side. *d.*, dens; *m.*, mucro; *s.o.*, scale-like organ.

71. The foot and distal extremity of the tibia of the first pair of legs.

72. The hamula. The apex of the organ is directed towards the hinder end of the animal. *c.*, corpus; *r.*, ramus; *s.*, seta.

73. Hairs and scales. (a) From the anterior border of the mesothorax. (b) From the fore leg. (c) From the general surface of the body.

74. The eyes of the right side.

PLATE XI.

Paronella börneri (continued).

Fig. 75. The insect viewed from above.

76. Entire leg of first pair.

Paronella gracilis, sp. n.

Fig. 77. The left foot of the first pair of legs seen from the inner side.

78. The left mucro seen from the inner side.

Paronella phanolepis (continued).

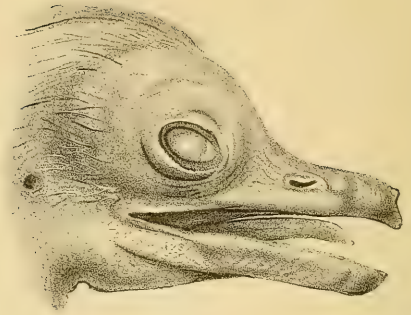
Fig. 79. The right mucro seen from the outer side.

Paronella insignis, sp. n.

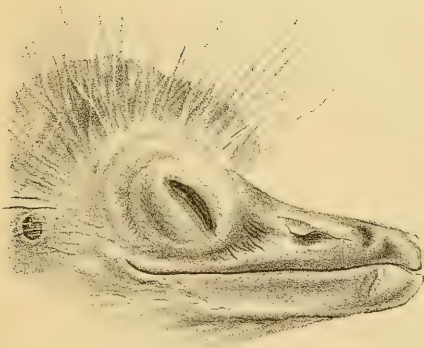
Fig. 80. The insect viewed from the left side.



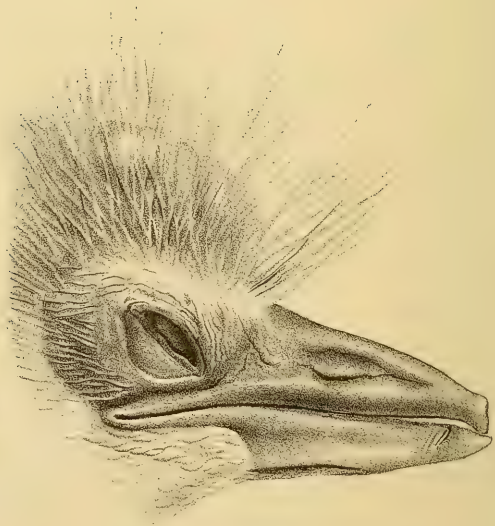
1



2



3



4

West, Newman lith.

DEVELOPMENT OF THE BILL IN ARDEA CINEREA.

PLATE XII.

Paronella insignis (continued).

Fig. 81. The right foot of the third pair of legs, seen from the outer aspect.

82. The right mucro seen from the outer aspect.

Sminthurides appendiculatus, sp. n.

Fig. 83. The left antenna seen from the inner side.

84. The left hind foot, inner side.

85. The left foot of the first pair of legs seen from the inner side.

86. The right mucro seen from its outer aspect. *d.i.l.*, dorsal inner lamella;
d.o.l., dorsal outer lamella; *v.l.*, ventral lamella.*Pseudocyphoderus annandalei*, gen. et sp. n.

Fig. 87. Foot of third pair of legs.

88. The furcula viewed from the dorsal side. *t.s.*, terminal scale.89. The left dens and mucro from the outer side. *t.s.*, terminal scale.*Cyphoderus simulans*, sp. n.

Fig. 90. The left foot of the second pair of legs.

91. The left mucro seen from its outer aspect.

8. Ontogenetical Transformations of the Bill in the Heron
(*Ardea cinerea*.) By Prof. P. P. SUSHKIN, C.M.Z.S.,
Kharkov, Russia.

[Received June 3, 1911: Read November 7, 1911.]

(Plate XIII.*)

The birds of the subfamily Ardeinæ are known to have a conical, pointed, spear-shaped bill with a simple rhamphotheca. The curious fact that these features are acquired only in a late post-embryonic stage seems to have attracted little attention. I have been able to trace a gradual development of these features in a series of embryos and young birds of *Ardea cinerea*, collected and generously presented to me by one of my friends, Mr. J. G. Sobolev, of Moscow.

In an embryo, in which the feather-papillæ on the back have just assumed a conical shape (length of the gape about 12 mm.), the bill is straight and rather slender, the tip of the upper jaw is conspicuously swollen (not only owing to the presence of the so-called egg-tooth), and the culmen is *concave*; a furrow runs from the nostril to the base of the swollen tip (Pl. XIII, fig. 1).

In an embryo about one day before hatching (length of gape 22 mm.) the form of the bill has already changed; it is thicker, its swollen tip is not so prominent and is slightly hooked, and the culmen is not so concave. The horny sheath of the bill is manifesting itself; the covering of the tips of both jaws is thicker and more solid, and the covering of the tip of the upper jaw is marked off by a raised area; a furrow anterior to the nostril, and a space

* For explanation of the Plate see p. 126.

of softer and finely wrinkled skin between the eye and the nostril divide the covering of the upper jaw into a dorsal and a paired lateral plate. The covering of the mandibular rami is marked by the presence of some parallel oblique ridges; these are perhaps still more conspicuous just at the time of hatching, but quickly disappear afterwards (fig. 2).

One day after hatching (length of gape 25 mm.) the bill is longer and conspicuously thicker, and the swelling of the tip has almost disappeared. The covering of the tip of the upper jaw is still marked off by its texture and relief, and the tip-covering of the mandible is marked off by two irregular crack-like furrows as well as by its solid texture. The division between the upper and lateral plates of the upper mandible is plainly visible (fig. 3).

About three days after hatching (length of gape 32 mm.) the bill has nearly assumed its conical shape, but is still relatively short and thick and the tip is still conspicuously hooked. The horny covering of the mandible-tip is still marked off by irregular furrows; in the upper jaw it is no more distinct; the lateral furrows before the nostril, dividing the upper and paired lateral horny plates, are still clearly visible (fig. 4).

These changes seem to deserve attention on more than one ground. The simple rhamphotheca proves to be only a late stage of the compound one, as very clear vestiges of separate pieces are visible in younger stages. In the upper jaw we find a tip piece, a dorsal piece, and a paired lateral piece; in the mandible there are a tip piece and a paired lateral piece. The form of the Ardeine bill proves to be a derivative one. The presence of the tip-hook in the nearest relatives of the Herons, *Scopus* and *Baleniceps*, is hence a primitive feature. In younger stages the shape of the bill, combined with its compound rhamphotheca, recalls very nearly that of a Cormorant, especially of a young one about the time of hatching, and also of the nestling of a Frigate-bird, and of a Pelican about the time of hatching. This points once more to the affinities of the Ardeæ and Steganopodes. The change in shape of the bill in the Ardeinæ is obviously due to their habits of *spearing* their prey instead of *snatching* as most of the Steganopodes do. The peculiar heron-like shape of the bill in the Darter (*Plotus ankinga*) is connected with the same habits, and the likeness of the bill's shape in the Herons and *Plotus* is to be considered as a case of parallel evolution. The transitory ridges on the mandibular rami recall remotely—by their direction also—the structures so much developed in the Anseres, and also, perhaps, the indentations of the bill in the fossil *Odontopteryx*.

EXPLANATION OF PLATE XIII.

Fig. 1. Bill and head of an embryo of *Ardea cinerea*, length of gape 12 mm.
1×2.

2. The same, one day before hatching. 1×1·75.

3. Young bird, one day after hatching. 1×1·5.

4. The same, about three days after hatching. 1×1·5.

9. The Duke of Bedford's Zoological Exploration of Eastern Asia.—XV. On Mammals from the Provinces of Szechwan and Yunnan, Western China. By OLDFIELD THOMAS, F.R.S., F.Z.S.*

[Received September 13, 1911 : Read October 24, 1911.]

After the departure of his assistants, Dr. J. A. C. Smith and Mr. Kingdon Ward, down the Yang-tze, with the remarkable collection of mammals which formed the subject of paper No. XIII. of the present series, Mr. Malcolm Anderson worked on by himself from September 1910 to the end of March 1911, when he brought back to Shanghai the series on which the present paper is based.

During this period he explored a number of localities in Western Szechwan and N. Yunnan, and has been rewarded by finding a considerable and quite unexpected number of species additional to those previously sent. He has been especially fortunate in discovering novelties among the Shrews and Voles, while of the peculiar little Insectivores allied to *Uropsilus* he has sent home the material on which I have found occasion to base two new genera.

Altogether the set consists of about 160 specimens belonging to 33 species, and no less than eleven prove to need description as new.

To our great loss and regret Mr. Anderson now proposes to give up the arduous life of the field collector, and this is therefore the last paper to be written on his collections for the Duke of Bedford's Exploration of Eastern Asia. On this account it is suitable to give a few words of appreciation for the manner in which he has risen to the opportunity afforded by our President's continued generosity.

From the commencement of the work in 1904 to the sending home of this last valuable collection in 1911 Mr. Anderson has worked for the Exploration with superb enthusiasm and success, and in the extent to which his collections have revolutionized our knowledge of an extended part of the earth's surface he has made a record which, so far as I know, has never been equalled, the nearest approach to it being Mr. C. H. B. Grant's collections for Mr. Rudd's Exploration of S. Africa†.

In turn Mr. Anderson has visited and collected in Japan and its islands, both the small southern ones and the large northern Hokkaido and Saghalien, Korea, N. China and Mongolia, Shen-si, Shan-si, Kansu, Szechwan and N. Yunnan, his collecting-localities being dotted through all the previously most unexplored parts of this little-known area.

Over 2700 mammals have been collected, besides many birds, and, as is natural, a large number of novelties have been found among them.

* Published by permission of the Trustees of the British Museum.

† Cf. P. Z. S. 1908, p. 555.

On this occasion it may be useful to give a list of the papers which have been written on the mammals collected by Mr. Anderson :—

- I. Japan. P. Z. S. 1905, vol. ii, p. 331. 60 spp.
- II. Korea and Quelpart. 1906, p. 858. 9 spp.
- III. Mindanao. 1907, p. 140. 6 spp.
- IV. Saghalien and Hokkaido. 1907, p. 404. 22 spp.
- V. Korea (II.). 1907, p. 462. 13 spp.
- VI. Shantung. 1908, p. 5. 6 spp.
- VII. Tsu-shima. 1908, p. 47. 11 spp.
- (VIII. Fishes of Korea. 1908, p. 59.)
- IX. Mongolian Plateau. 1908, p. 104. 9 spp.
- X. Chih-li and Shan-si. 1908, p. 635. 20 spp.
- XI. Shan-si and Shen-si. 1908, p. 963. 33 spp.
- XII. S. Shen-si. 1910, p. 635. 3 spp. nn.
- XIII. Kansu and Sze-chwan. 1911, p. 158. 48 spp.
- XIV. S. Shen-si. 1911, p. 687. 31 spp.
- XV. Sze-chwan and Yunnan. 1912, p. 127. 32 spp.

The localities at which the present collection was made being somewhat scattered, and but little known, it may be helpful to give a list of them :—

Chin-fu-san, a mountain near the city of Nan-chwan, south of Chung-king, not far north of the Sze-chwan-Kwei-chow border.

Hwa-yin-san, a limestone peak 50 miles N.E. of Chung-king.

Caves near Pen-hsien, about 35 miles N.W. by N. of Chen-tu.

Wei-choe, about 60 miles N.W. of Chen-tu, in the narrow valley of the Si-ho (or Sung-pan-ho).

Wen-chwan, 12 miles lower down the Si-ho.

Yuen-ching-hsien, S.W. of Ya-chow. "Part of the humid range in which Mount Omi lies."

Ning-yuen-fu, S. of Fu-lin, on the Tung-ho.

Chao-tung-fu, N. Yunnan, about 103° 40' E., 27° 30' N.

1. *SIMIA* * sp. (*S. rhesus* group).

♀. 2678. Mts. 30 miles S.W. of Kia-ting-fu, Sze-chwan.

2. *RHINOLOPHUS FERRUM-EQUINUM* Schr.

♂. 2592 (in al.). Caves near Pen-hsien, 35 miles N.W. of Chen-tu. 3000'.

3. *RHINOLOPHUS CORNUTUS PUMILUS* K. And.

♀. 2587, 2588, 2589, 2590 (in al.), 2591 (in al.). Caves near Pen-hsien, 35 miles N.W. of Chen-tu. 3000'.

4. *HIPPOSIDEROS ARMIGER* Hodgs.

♂. 2585, 2586. Caves near Pen-hsien, Central Sze-chwan, 3000'.

* *Simia* Linnaeus. Type *S. sylvestris*, the Barbary Ape; *Macaca* and *Pithecus* auctorum: see Thomas, P. Z. S. 1911, p. 125.

5. *NYCTALUS PLANCYI* Gerbe.

♂. 2677. Ya-chow-fu, Sze-chwan. 2500'.

This Bat is just distinguishable—by its rather smaller size—from the Nepalese *N. labiatus* Hodgs., with which it shares the reduced length of the outer incisors.

6. *UROSILUS SORICIPES* M.-Edw.

♂. 2605, 2637. Wei-choe, on Si-ho River, W. Sze-chwan. 9000'–12,500'.

Much to my surprise, these specimens show that, in spite of the nearness of the localities and the almost complete identity of external and cranial characters, the examples from Mt. Omi referred in my previous paper to *U. soricipes*, with a note on the discrepancy in the dental formula, belong to a distinct species altogether—that discrepancy being the distinguishing characteristic.

For these two specimens, like that figured by Milne-Edwards and another one from Père David's series kindly lent me by Prof. Trouessart, have no trace either of the minute p^3 or i_3 , both present in the Omi species, nor any space in which they could have stood. We must therefore accept the formula given by Milne-Edwards as correct, and assign these examples to his species.

This being the case, the Omi animal, with a constantly different formula, will need not only description as a new species, but the formation of a special genus for its reception.

And, furthermore, a single example of the group from Chin-fu-san proves to have yet another formula, the small upper premolar being present, and indeed better developed than in the Omi form, the additional lower incisor is absent, while, alone in the group, a p_3 is present.

The three animals may be briefly diagnosed as follows:—

UROSILUS.

Teeth $\frac{9}{8} \times 2 = 34$, neither p^3 , p_3 , nor i_3 present, the adult formula being therefore

$$\begin{array}{c} 1. \quad 1. \quad 2. \quad 0 \\ 0. \quad 2. \quad 0 \end{array} \quad C. \quad \frac{1}{1} \quad P. \quad \frac{1. \quad 2. \quad 0. \quad 4}{1. \quad 2. \quad 0. \quad 4} \quad M. \quad \frac{1. \quad 2. \quad 3}{1. \quad 2. \quad 3}$$

U. soricipes. Size fairly large. Colour near “sepia”; underside of tail lighter than upper. (Winter specimens only seen.)

NASILUS Thos.

Teeth $\frac{10}{9} \times 2 = 38$; p^3 and p_3 present; no i_3 (detailed formula below).

Type. *N. gracilis*.

RHYNCHONAX THOS.

Teeth $\frac{10}{9} \times 2 = 38$; p^3 and i_3 present; no p_3 . Complete dental formula as follows:—

$$I. \begin{cases} 1 & 2 & 0 \\ 1 & 2 & 0 \\ 0 & 2 & 3 \\ 0 & 2 & 3 \end{cases} \quad C. \begin{cases} 1 \\ 1 \\ 1 \\ 1 \end{cases} \quad P. \begin{cases} 1 & 2 & 3 & 4 \\ & 2 & 3 & 4 \\ & 2 & 3 & 4 \\ 1 & 2 & 0 & 4 \end{cases} \quad M. \begin{cases} 1 & 2 & 3 \\ 1 & 2 & 3 \end{cases}$$

Type:—RHYNCHONAX ANDERSONI.

Uropsilus soricipes Thos. P. Z. S. 1911, p. 163, nec M.-Edw.

R. andersoni Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

Size comparatively large. Colour dark, approaching "clove-brown," the lighter specimens near "bistre." Under surface dark slaty. Tail scaly, almost naked, scarcely lighter below than above (summer specimens only seen). Teeth described *l. c.*, but the dental formula there given proves to be incorrect and should be as above.

Dimensions of the type, measured in the flesh:—

Head and body 70 mm.; tail 67; hind foot 15.5.

Skull: greatest length 21.7; basal length 17.5; zygomatic breadth 11.6; interorbital length 5.5; breadth of brain-case 11.3; upper tooth-series 9.7.

Hab. Omi-san, Omi-hsien, S. Sze-chwan. 9500'.

Type. Adult male. B.M. No. 11.2.1.25. Original number 2504. Collected 15 August, 1910. Nine specimens examined.

In naming this final species after Mr. Malcolm Anderson, I would recall not only the wonderful success he has made of the whole expedition, but also the extent to which he has increased our material, and with it our knowledge, of this particular group of Mammals. Practically the whole of our magnificent series of *Urotrichus* was obtained by him, including the specimens on which three new subspecies were founded, all our *Uropsilus*, *Rhynchonax*, and *Nasillus* were sent by him, while even our examples of *Dymecodon* were obtained by a Japanese whom he had taught to collect.

7. NASILLUS GRACILIS.

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

♀. 2566. Mt. Chin-fu-san, near Nan-chwan, S.E. Sze-chwan. 4000'. 20 September, 1910. B.M. No. 11.9.1.13. *Type.*

A comparatively small species, with peculiar dental formula.

Size decidedly less than in the other species, the hind foot 1-2 mm. shorter, and the skull smaller in all dimensions. General colour above near "sepia," very much as in *Uropsilus soricipes*, *Rhynchonax andersoni* being darker. Under surface

slaty. Hands and feet pale brown. Tail uniformly brown above and below.

Skull shorter and decidedly narrower than in either of the other species; the brain-case less expanded laterally.

Dentition:—

$$I. \begin{smallmatrix} 1.2.0 \\ 0.2.0 \end{smallmatrix} \quad C. \frac{1}{1} \quad P. \begin{smallmatrix} 1.2.3.4 \\ 1.2.3.4 \end{smallmatrix} \quad M. \frac{1.2.3}{1.2.3} = \frac{10}{9} \times 2 = 38.$$

Upper p^3 (the tooth which is absent in *Uropsilus soricipes* and minute in *Rhynchonax andersoni*) comparatively large, as large as the small anterior premolar in the horizontal area. Below there is no trace of a minute incisor (i_3) behind the large anterior tooth, but, on the other hand, alone in the group, a p_3 is present behind the tooth wrongly taken in my previous paper for p_3 , but really p_2 ; it is slightly smaller than the corresponding tooth in the upper jaw and is therefore the smallest tooth present in the animal.

Dimensions of the type, measured in the flesh:—

Head and body 66 mm.; tail 55; hind foot 13.5; ear 9.

Skull: greatest length 20.5; basal length 16.5; zygomatic breadth 10; interorbital breadth 5; breadth of brain-case 10; upper tooth-series 9.1.

Hab. and *Type* as above.

This delicate little species proves to be of much interest, as its peculiar dentition has caused the discovery of the error in the dental formula of *Rhynchonax* (under the name of *Uropsilus*) previously published, and indicates that that animal has in the lower jaw the very unusual premolar formula 1.2.0.4, a formula which in *Uropsilus* occurs in the upper jaw as well.

This being the case, it is natural to examine again the dentitions of the nearly allied *Urotrichus*, *Dymecodon*, and *Neurotrichus*, and after some consideration I venture to put forward the following as their formulæ, modifying those I had previously published:—

Urotrichus:—

$$I. \begin{smallmatrix} 0.2.3 \\ 0.2.0 \end{smallmatrix} \quad C. \frac{1}{1} \quad P. \begin{smallmatrix} 1.2.0.4 \\ 1.2.0.4 \end{smallmatrix} \quad M. \frac{1.2.3}{1.2.3} = \frac{10}{8} \times 2 = 36.$$

Dymecodon:—

$$I. \begin{smallmatrix} 1.2.3 \\ 0.2.3 \end{smallmatrix} \quad C. \frac{1}{1} \quad P. \begin{smallmatrix} 1.2.0.4 \\ 1.2.0.4 \end{smallmatrix} \quad M. \frac{1.2.3}{1.2.3} = \frac{10}{9} \times 2 = 38.$$

Neurotrichus:—

$$I. \begin{smallmatrix} 1.2.3 \\ 0.2.3 \end{smallmatrix} \quad C. \frac{1}{1} \quad P. \begin{smallmatrix} 0.2.0.4 \\ 1.2.0.4 \end{smallmatrix} \quad M. \frac{1.2.3}{1.2.3} = \frac{9}{9} \times 2 = 36.$$

It will be seen that, arguing from the analogy of the minute teeth of *Rhynchonax*, which are missing in *Uropsilus*, I suggest that it is the third lower incisor which is missing in *Urotrichus*,

and that in all, when one premolar is absent, it is the third and not the second, whether above or below.

Of course these formulæ are still merely provisional, and liable to modification when good examples of the respective milk-dentitions are available for examination.

8. *SOREX CYLINDRICAUDA* M.-Edw.

♀. 2672. Near Yuen-ching-hsien, Sze-chwan. 5200'.

9. *SOREX WARDI FUMEOLUS*.

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

♂. 2606, 2616, 2627, 2657. ♀. 2638, 2656. Wei-choe, on Si-ho River, W. Sze-chwan. 6000'–11,000'.

Larger and darker-coloured than true *wardi*, the brain-case broader. Fur about 6 mm. in length (winter). General colour nearly the same brown as in *S. bedfordiæ* or a little greyer, decidedly darker than in *S. wardi*. Dark dorsal line well marked in all the specimens, rather more diffuse than in the other striped species, but this may be due to the greater length of the winter coat. Under surface markedly greyer than upper ("smoke-grey"), while in *S. bedfordiæ* there is little difference between the two.

Skull, like that of *S. wardi*, at once distinguishable from that of *S. bedfordiæ* by its lower and less vaulted brain-case. From that of the type of *S. wardi* it is separated by the rather larger size and by the distinctly greater breadth of the low flat brain-case.

Dimensions of the type, measured in the flesh :—

Head and body 60 mm.; tail 60; hind foot 13; ear 8.

Skull : condylo-basal length 18.1; condylo-incisive length 18.5; breadth across brain-case 8.4; upper tooth-series 8.1; height of brain-case from basion 4.6.

Hab. as above.

Type. Adult male. B.M. No. 11.9.8.17. Original number 2627. Collected 24 November, 1910.

This little striped Shrew has a considerable resemblance to *S. bedfordiæ*, but its flattened skull indicates that it is really more allied to *S. wardi*, of which it may be considered a darker-coloured representative.

10. *SORICULUS IRENE*.

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

♂. 2674. ♀. 2673. Yuen-ching-hsien, S.W. Sze-chwan. 5200'.

General characters of *S. macrurus*, but brain-case much lower.

Size about as in *S. macrurus*. Fur soft and fine; hairs of back (winter) about 6.5 mm. in length; about 5.0 mm. in what I believe to be summer specimens of the same species. General colour above uniform slaty grey (grey no. 4); under surface paler,

near smoke-grey. Hands and feet whitish, a little darkening on the metatarsals. Tail long and slender, uniformly grey-brown above, whitish below. In the summer specimens the underside of the tail is scarcely lighter than the upper.

Skull quite like that of *S. macrurus*, except that the brain-case is conspicuously lower, the height nearly a millimetre less, the length and width being about the same. Teeth rather more heavily pigmented.

Dimensions of the type, measured in the flesh :—

Head and body 60 mm.; tail 90; hind foot 16; ear 10.5.

Skull: condylo-incisive length 17.8; condylo-basal length 17.2; greatest breadth 9; height of brain-case from basion 4.9; length of upper tooth-series 7.4.

Hab. of type as above; specimens from Mt. Omi believed to be the same.

Type. Adult female. B.M. No. 11.9.8.22. Original number 2673. Collected 13 January, 1911.

The specimens from Mt. Omi collected in August, 1910, are darker-coloured and their tails are scarcely lighter below, but they agree with the Yuen-ching examples in all other characters, and it seems probable that their differences are merely seasonal. They were formerly identified by me with *S. macrurus* of Darjiling, their distinctive character, the much lower brain-case, not becoming evident until the arrival of the present additional material.

11. CHODSIGOA HYPsIBIA de Wint.

♀. 2604, 2642. Wei-choe, on Si-ho River, W. Sze-chwan, 5900'–7000'.

These Shrews, collected in mid-winter, bear the same relation in colour to de Winton's type that the winter specimens of *Soriculus irene* do to those which I consider to be summer skins of the same animal, their grey being similarly paler and their tails more whitish. The type locality is by no means distant, nor is that of *Ch. berezowskii*, which, as previously stated, I believe to be of the same species.

The skulls of these specimens, however, being perfect, indicate that the *Chodsigoa* previously obtained by Mr. Anderson in Chih-li, and assigned to *Ch. hypsibia*, must be separated specifically. It may be called

CHODSIGOA LARVARUM.

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

General characters of *Ch. hypsibia*, brain-case narrower and less flattened.

Fur close and fine; hairs of back about 3.8 mm. in length. General colour above "mouse-grey," rather lighter, apparently "smoke-grey" below. Hands and feet whitish. Tail brown above, dull whitish brown below.

Skull, although showing the peculiar flattening and concavity of the upper profile-line characteristic of the genus, not so extreme as that of *Ch. hypsibia*, the top of the brain-case fairly vaulted, and the sides not splayed out. Teeth quite as in *Ch. hypsibia*.

Dimensions of the type, measured in the flesh:—

Head and body 68 mm.; tail 50; hind foot 14; ear 8.5.

Skull: condylo-incisive length 19.8; condylo-basal length 18.8; greatest breadth across brain-case 8.8; height of brain-case from basion 5; upper tooth-series 8.6.

Hab. Imperial tombs, 65 miles E. of Peking, Chih-li. 1000'.

Type. Adult female. B.M. No. 8.8.7.21. Original number 1559. Collected 25 September, 1907, by M. P. Anderson. Two specimens.

12. *BLARINELLA QUADRATICAUDA* M.-Edw.

♀. 2567. Near Nan-chwan, S.E. Sze-chwan. 4000'.

13. *CROCIDURA ATTENUATA* M.-Edw.

♀. 2565, 2572, 2573. Chin-fu-san, near Nan-chwan, S.E. Sze-chwan. 4000'.

♂. 2575, 2581. ♀. 2576. Mts. 50 miles N.E. of Chung-king. 3000'.

14. *ANOURESOREX SQUAMIPES* M.-Edw.

♀. 2570, 2574. Chin-fu-san, near Nan-chwan, S.E. Sze-chwan. 4000'.

♀. 2577, 2582. Mts. 50 miles N.E. of Chung-king. 3000'.

♂. 2675. Near Yuen-ching-hsien, W. Sze-chwan.

♂. 2693, 2697, 2698, 2708. ♀. 2707. 21 miles N.E. of Chao-tung-fu, Yunnan. 5800'.

15. *ARCTONYX OBSCURUS* M.-Edw.

♀. 2651, 2662, 2663. Wei-choe, Si-ho R., W. Sze-chwan. 7000'.

16. *SCIURUS CASTANEOVENTRIS BONHOTI* Robinson & Wrought.

♀. 2676. Yuen-ching-hsien, S.W. of Ya-chow, Sze-chwan. 3000'.

♀. 2679. Ning-yuen-fu, S. of Fu-lin, S.W. Sze-chwan.

This subspecies has only been recently distinguished on the basis of Sze-chwan specimens presented to the Museum by Mr. F. W. Styan.

"A forest-loving species; rare."—M. P. A.

17. *SCIUROTAMIAS DAVIDIANUS CONSOBRINUS* M.-Edw.

♀. 2669. Wen-chwan-hsien, Si-ho R., Sze-chwan. 6000'.

18. *EPIMYS HUMILIATUS* M.-Edw.

♀. 2701. 21 miles E. of Chao-tung-fu, N. Yunnan. 5800'.

This is an interesting animal as being a wild species closely allied to the ubiquitous pest, *E. norvegicus*, from which it chiefly differs by its smaller size. The flesh-measurements of Mr. Anderson's specimens are as follows:—Head and body 160 mm.; tail 130; hind foot 29; ear 17.

Milne-Edwards's *Mus plumbeus* appears to be the young of the same form, and it is also probable that his *M. ouang-thomæ* is not distinguishable from it.

19. *EPIMYS CONFUCIANUS* M.-Edw.

♂. 2568, 2569 (young). Chin-fu-san, near Nan-chwan, S.E. Sze-chwan. 4000' (September).

♂. 2583. ♀. 2584 (young). Hwa-yin-san, 50 miles N.E. of Chung-king. 4000' (October).

♂. 2594, 2600, 2602, 2603, 2641, 2643, 2658. ♀. 2599, 2659. Wei-choe, on Si-ho R., W. Sze-chwan. 5900'–7000' (November–December).

♂. 2682. 21 miles E. of Chao-tung-fu, Yunnan (March).

The September and October specimens are distinctly spinous, the others quite soft-furred.

20. *APODEMUS CHEVRIERI* M.-Edw.

♂. 2595, 2596, 2608. Wei-choe, Si-ho R., W. Sze-chwan. 5900'–7000'.

♂. 2680, 2681, 2682, 2683, 2688, 2689, 2691. ♀. 2686, 2687, 2690. 30 miles S.E. of Ning-yuen-fu, S. Sze-chwan. 4500'.

♂. 2716, 2722. ♀. 2712, 2713, 2717, 2723, 2724, 2727. Chao-tung-fu, N. Yunnan. 6400'.

A. agrarius group. Tail and ears comparatively short. M^2 without antero-external secondary cusp. M^3 with only two internal projections.

On finding both this species and the next in considerable numbers in the Sze-chwan collection, I have thought it advisable to verify the determination of Milne-Edwards's *Mus chevrieri*, which, thanks to the kindness of Prof. Trouessart, I have now been able to do.

To my great regret I find that my suspicions about the determination were justified, and that, instead of being the common and widely spread species allied to *A. speciosus*, as has been supposed, *chevrieri* is the rarer shorter-tailed form only recently sent us by Messrs. Anderson and Fergusson, the mouse I described as *A. fergussoni* being the same species, though perhaps subspecifically separable.

Fortunately, like as the two species are externally, the determination of specimens is easy enough by the dental characters given above, characters which show clearly in Milne-Edwards's type, although the teeth are worn down.

In all papers previous to this therefore* the name *chevrieri* must be entirely withdrawn from the member of the *speciosus* group to which it has been wrongly attached.

With regard to *fergussoni*, more material from Kan-su is needed before its characters can be elucidated; but there is some evidence that the northern specimens of *chevrieri*, e. g. those from Wei-choe, have less fulvous suffusion on the hinder back than the southern ones, the type of *fergussoni* being completely without it. For the present, therefore, we may provisionally call the Kan-su form *Apodemus chevrieri fergussoni*, with the Wei-choe specimens as connecting intermediates.

21. APODEMUS SPECIOSUS PENINSULÆ THOS.

♂. 2578, 2580. ♀. 2579. Hwa-yin-san, 50 miles N.E. of Chung-king. 3000'.

♂. 2598, 2647, 2649, 2652, 2653, 2661. ♀. 2593, 2597, 2601, 2644, 2645, 2646, 2648, 2650, 2655, 2660. Wei-choe, Si-ho R., W. Sze-chwan. 5900'-7500'.

A. speciosus group. Tail and ears comparatively long. Molars more complicated; m² with antero-external secondary cusp; m³ with three internal projections.

22. APODEMUS SPECIOSUS ORESTES.

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

A. s. chevrieri M.-Edw., Thos. P. Z. S. 1911, p. 172 (in part.).

♂. 2610, 2622, 2624, 2636, 2654. ♀. 2623, 2625, 2626, 2635. Wei-choe, R. Si-ho. 7000'-12,000'.

As explained above, the common long-tailed Field-mouse of Sze-chwan proves to have no claim to the name *chevrieri*, hitherto supposed to be applicable to it, and we have now to consider what it should be called.

On laying out again the fine series received from Mr. Anderson, we find, to start with, that the specimens from Mt. Omi are uniformly dark-coloured and clearly form a race distinct from the pale *A. s. peninsularis*.

This may be called

A. S. ORESTES.

Size about as in *A. s. peninsulæ* or rather larger. Tail longer than head and body. Ears of medium size. Colour very dark, the back (in summer specimens) slightly more rufous than Ridgway's "sepia." Under surface grey no. 7.

Skull slenderly built, of medium size.

Dimensions, taken in the flesh:—

	Type.	Extremes of Omi series.
Head and body	93 mm.	85 - 98 mm.
Tail	125 "	102 -125 "
Hind foot	24 "	22.5- 25 "
Ear	16 "	15.5- 18 "

* From Barrett-Hamilton, P. Z. S. 1900, p. 418 onwards.

Skull: greatest length 27.5 mm.; condylo-incisive length 24.8; interorbital breadth 4.7; palatilar length 11.8; palatal foramina 5.7; upper molar series 4.2.

Typical locality. Mt. Omi, W. Sze-chwan. 6000'-10,000'.

Type. Adult male. B.M. No. 11.2.1.170. Original number 2535. Collected 18 August, 1910.

This subspecies differs from *peninsulae* by its darker colour and from the W. Fokien *draco* B.-Ham. by its larger size, longer tail, and less rufous tone.

The Wei-choe series of the present collection contains examples agreeing with *peninsulae* and others with *orestes*, and on examination it proves that all of the latter are from altitudes above 7000', while all of the former are below that height. On the other hand, on Mt. Omi those from 6000' are of quite the same colour as those from 9000', so that it cannot be said that the darker colour is a direct result of the altitude.

23. *APODEMUS SPECIOSUS LATRONUM.*

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

♂. 2726, 2728. Chao-tung-fu, Yunnan. 6400'.

(Series from Ta-tsien-lu previously enumerated.)

A large form, with large ears and comparatively short tail.

Size decidedly larger than in *A. s. orestes*. General colour above near "broccoli-brown"; under surface grey no. 7, the hairs slaty basally, whitish terminally. Ears very large, their visible surfaces black. Hands and feet white. Tail ranging from a little shorter to a little longer than the head and body, blackish above, white below.

Skull conspicuously larger than in the other W. Chinese forms, as large as in true Japanese *speciosus*.

Dimensions:—

	Type.	Extremes of Ta-tsien-lu series.
Head and body	107 mm.	95-108 mm.
Tail	101 "	100-115 "
Hind foot	25 "	24- 26 "
Ear	20 "	18- 20 "

Skull: greatest length 29.6 mm.; condylo-incisive length 26.6; interorbital breadth 4.3; palatilar length 12.8; palatal foramina 6.1; upper molar series 4.6.

Typical locality. Ta-tsien-lu, W. Sze-chwan. 9000'.

Type. Adult male. B.M. No. 11.2.1.156. Original number 2377. Collected 30 June, 1910.

This distinct large-eared form would seem to range over the mountainous country to the west and south of the area inhabited by *A. s. orestes*.

24. *MICROMYS PYGMEUS* M.-Edw.

♂. 2684, 2685. 30 miles S.E. of Ning-yuen-fu, S.W. Sze-chwan. 4500'.

25. MICROTUS MILLICENS.

Thos. Abstr. P. Z. S. 1911, p. 49 (Oct. 31).

♂. 2613, 2614, 2615, 2621, 2639. ♀. 2632, 2640. Wei-choe, on Si-ho R., W. Sze-chwan. 12,000'–12,500'.

A greyish species with a delicate flattened skull, long tail, and extra angle on m^2 .

Size medium, about as in *M. irene*. Fur long, soft, and loose; hairs of back (in winter pelage) about 12 mm. in length. General colour above rather darker than "hair-brown," passing into "smoke-grey" below. Ears scarcely projecting above the fur, well-haired, greyish brown. Head and feet glossy greyish white, varying to greyish brown; soles with 6 pads. Tail comparatively long, well-haired, grey-brown above, whitish below. Mammary 2—2=8.

Skull rather lightly built, with a long flattened oval brain-case without marked ridges or angles. Upper profile-line flat or even slightly concave at a point above m^2 . Rostrum of medium length, narrow. Interorbital region smooth, not ridged, flattened above. Angles of brain-case scarcely perceptible. Posterior palate normal, the lateral pits of medium depth.

Incisors rather thrown forward. Molars narrow. M^1 with the usual five spaces, all separated, a scarcely perceptible trace of a supplementary postero-internal projection. M^2 with a large supplementary postero-internal salient angle, making three angles on the inner side. M^3 narrow, with the usual transverse first space, the second and third small, united to each other, and a posterior **U**; three inner and three outer salient angles (the whole somewhat as in Blasius's figure 221*, except that the anterior transverse lobe is narrower, and the second and third spaces are united). M_1 with a large posterior transverse lobe, four lateral closed triangles in front of it, and a fifth united to the anterior trefoil, there being in all five inner and four outer salient angles (near fig. 193 of Blasius, if the first lateral closed triangle were open to the anterior trefoil). M_2 with the anterior two of the usual five spaces united to each other; three inner and three outer angles.

In short, the most salient features of the dentition are the development of the extra postero-internal angle on m^2 and the junction of the second and third spaces of m^3 and first and second of m_2 .

Dimensions of the type, measured in the flesh:—

Head and body 90 mm.; tail 53; hind foot 18·5; ear 14.

Skull: condylo-basal length 24·3; condylo-incisive length 24·6; zygomatic breadth 14·2; nasals 6·7; interorbital breadth 4·2; brain-case, length 12·5, breadth 11·5, height including bullæ 9, height of supraorbital edge above root of m^2 6·9; palatilar length 12·5; palatal foramina 4·8; upper molar series (crowns) 5·6.

Hab. as above.

* J. H. Blasius, *Naturl. der Säugethiere Deutschlands*, 1857.

Type. Adult male. B.M. No. 11.9.8.105. Original number 2615. Collected 20 November, 1910.

This striking species, from the considerable altitude of 12,000', is readily recognizable by its smooth flattened skull and long tail, the latter character separating it at once from *M. irene*, to which alone of the Chinese species hitherto described it has any resemblance.

In its possession of an extra angle on m^2 it has a curious likeness to many of the species of *Eothenomys* and *Caryomys*, this character in true *Microtus* being only hitherto known in *M. agrestis* L. and *sikimensis* Hodgs.

26. *MICROTUS (EOTHENOMYS) MELANOGASTER ELEUSIS.*

Thos. Abstr. P. Z. S. 1911, p. 50 (Oct. 31).

♂. 2694, 2695, 2696, 2700, 2703, 2704, 2709, 2710, 2711.

♀. 2699, 2702, 2705, 2706. 21 miles east of Chao-tung-fu, N. Yunnan. 5800'.

[?♂. 2571. Chin-fu-san, near Nan-schwan, S.E. Sze-chwan. 4000'.]

Longer-tailed than true *melanogaster*, with more complicated m^3 .

General characters quite as in true *melanogaster*, though the colour may average slightly more greyish brown. Head and feet dark. Tail decidedly longer than in *melanogaster*, the shortest measured 43 mm., the majority about 46 or 48, and the longest 55; on the other hand, in a number of *melanogaster* the majority are 34–36, a single isolated example 43.

Skull and teeth as in *melanogaster*, except that m^3 is in nearly all cases more complicated, the posterior U-shaped lobe being rather a C, so that there are four inner salient angles instead of three.

Dimensions of the type, measured in the flesh:—

Head and body 98 mm.; tail 55; hind foot 17; ear 11.5.

Skull: condylo-incisive length 24.7; basilar length 22; zygomatic breadth 15; nasals 7.4; interorbital breadth 4.2; breadth of brain-case 12.3; height of crown above alveolus of m^2 7.7; palatilar length 11.8; palatal foramina 5.1; upper molar series (crowns) 5.6.

Hab. East of Chao-tung-fu, N. Yunnan. 5800'.

Type. Adult male. B.M. No. 11.9.8.111. Original number 2696. Collected 13 March, 1911.

The Chin-fu-san specimen is a little indeterminate in character, the teeth of the two sides not being quite alike.

27. *MICROTUS (EOTHENOMYS) OLITOR.*

Thos. Abstr. P. Z. S. 1911, p. 50 (Oct. 31).

♂. 2718. ♀. 2714, 2715, 2719, 2720, 2721, 2725. Chao-tung-fu, Yunnan. 6700'.

A short-tailed sepia-brown *Eothenomys* without supplementary projection on m^1 .

Size rather smaller than in *M. (E.) melanogaster*. General colour a less warm brown than in that animal, the upper surface nearest to "sepia"; under surface dark slaty grey (rather more smoky than "grey no. 5"). Hands and feet brown, soles with 6 pads. Tail dark brown above, little lighter below.

Skull rather smaller than that of *M. melanogaster*, but similar to it in general form; the bullæ not quite so large.

Teeth agreeing with those of *melanogaster* in the junction to each other of nearly all the opposite spaces of the teeth, and therefore equally differing from the members, now four in number, of the subgenus *Caryomys*. But they are readily distinguished by the fact that m^1 has not got the characteristic supplementary postero-internal salient projection occurring in both m^1 and m^2 of *melanogaster*, and here present of full size in m^2 ; as a result, there are three internal angles on both these teeth. M^3 more complicated than in *melanogaster*, with four salient angles on each side; it consists of three separated dentine spaces, the first with one inner and two outer angles, the middle one with one external and one internal angle, and the posterior with two internal and one antero-external angle. Lower teeth essentially as in *melanogaster*, the spaces all opposite and united.

Dimensions of the type, measured in the flesh:—

Head and body 82 mm.; tail 34; hind foot 16; ear 9.

Skull: condylo-incisive length 24; zygomatic breadth 15.4; nasals 6.8; interorbital breadth 4; height of crown from alveolus of m^2 7.5; breadth of brain-case 11; palatilar length 11.5; palatal foramina 4.7; upper molar series (crowns) 5.5.

Hab. as above.

Type. Adult female. B.M. No. 11.9.8.122. Original number 2714. Collected 19 March, 1911.

The dentition of this Vole is interesting, as it conforms strictly to the *Eothenomys* as opposed to the *Caryomys* type, while presenting such differences from that of *M. (E.) melanogaster* as readily to distinguish the two species.

"Trapped in the open fields of the little cultivated plain surrounding the city."—M. P. A.

28. *MICROTUS (CARYOMYS) ALCINOUS*.

Thos. Abstr. P. Z. S. 1911, p. 50 (Oct. 31).

♂. 2609, 2611, 2612, 2617, 2618, 2620, 2628, 2629, 2630, 2631, 2633, 2634. ♀. 2619. Wei-choe, Si-ho R., W. Sze-chwan. 8000'–12,000'.

Essential characters as in *M. (C.) eva*, but colour much darker.

Proportions, skull, and teeth all about as in *eva*. Fur long and soft; hairs of back about 9–10 mm. in length (winter). General colour above uniform dark bistre-brown, conspicuously different from the pale brown *M. eva*; under surface dark smoky grey, decidedly darker than Ridgway's "smoke-grey." Ears about as long as the fur, their backs with some whitish

hairs on them, making an inconspicuous grey patch. Hands and feet dark brown. Tail as long as in *M. eva*, blackish above, little lighter below.

Skull apparently very much as in *M. eva*, though the bullæ are perhaps a little smaller.

Dimensions of the type, measured in the flesh:—

Head and body 90 mm.; tail 56; hind foot 17; ear 11.5.

Skull: greatest length 24; condylo-incisive length 23.8; zygomatic breadth 14; nasals 7; interorbital breadth 4.3; breadth of brain-case 11.3; height of crown from alveolus of m² 7.1; palatilar length 11.2; palatal foramina 5; upper molar series (crowns) 5.7.

Hab. as above.

Type. Adult male. B.M. No. 11.9.8.136. Original number 2631. Collected 24 November, 1910.

The close agreement of this species with *M. (C.) eva* in its proportions, notably in the unusually long tail and in its skull and dentition, is remarkable, as in its colour it is so entirely different that one would have expected to find distinguishing characters in other respects.

29. CAPRICORNIS MILNE-EDWARDSI David.

♀. 2667. Wen-chwan-hsien, Si-ho R., W. Sze-chwan.

"Inhabits the forests and cliffs at altitudes above 6000'. It is not so common as *Nemorhedus cinereus*."

"Chinese name 'Ngai-lui' = Cliff Donkey, probably so called because of the long ears."—M. P. A.

30. NEMORHEDUS CINEREUS M.-Edw.

♂. 2665, 2666. ♀. 2664, 2671 (imm.). Wen-chwan-hsien, Si-ho R., W. Sze-chwan. 6000'–7000'.

31. ELAPHODUS CEPHALOPHUS M.-Edw.

♂. 2668. Wen-chwan-hsien, Si-ho R., Sze-chwan. 8000.

In the dark winter pelage, that figured by Milne-Edwards being in the rufous summer coat.

"Very shy and retiring, but not really rare."—M. P. A.

32. MOSCHUS SIFANICUS Büchn.

♂. 2670 (imm.). Wen-chwan-hsien, Si-ho R., W. Sze-chwan.

EXHIBITIONS AND NOTICES.

November 21, 1911.

S. F. HARMER, Esq., M.A., Sc.D., F.R.S., Vice-President,
in the Chair.

THE SECRETARY read the following report on the additions made to the Society's Menagerie during the month of October 1911 :—

The number of registered additions to the Society's Menagerie during the month of October last was 287. Of these 141 were acquired by presentation, 42 by purchase, 34 were received on deposit, 28 in exchange, and 42 were born in the Gardens.

The number of departures during the same period, by deaths and removals, was 391.

Amongst the additions special attention may be directed to :—

1 Budgett's Cercopitheque (*Cercopithecus tantalus budgetti*), 2 Matschie's Guerezas (*Colobus matschiei*), and 1 Shari River Hunting-Dog (*Lycaon pictus sharicus*), new to the Collection, from the Northern Congo, deposited on October 12th.

1 Duke of Bedford's Wapiti (*Cervus xanthopygius*) ♂, from Manchuria, deposited on October 9th.

1 Waterhouse's Genet (*Genetta poënsis*), from S. Nigeria, new to the Collection, presented by W. A. Lambourne, Esq., on October 1st.

1 Indian Redstart (*Ruticilla rufiventris*), new to the Collection, received in exchange on October 25th.

3 Myrtle Warblers (*Dendroica coronata*), new to the Collection, from North America, presented by E. Hollman, Esq., on October 25th.

4 Peale's Parrot-Finches (*Erythrura pealei*), from the Fiji Islands, presented by Dr. Philip H. Bahr, F.Z.S., on October 19th.

1 Rainbow-Bunting (*Cyanospiza leclancheri*), from Western Mexico, new to the Collection, received in exchange on October 6th.

1 Malayan Wrinkled Hornbill (*Rhytidoceros undulatus*), received in exchange on October 6th.

2 Ring-necked Teal (*Nettion torquatum*), from South America, new to the Collection, received in exchange on October 20th.

Mr. R. I. Pocock, F.R.S., F.L.S., F.Z.S., Superintendent of the Gardens, exhibited a living specimen of the Common Elephant-Shrew (*Macroscelides proboscideus*) (text-fig. 16), which had been captured at Tuin in Bushmanland and presented to the Society by Capt. H. A. P. Littledale, who sent at the same time a second example of the same species, an example of the Rock Elephant-Shrew (*Elephantulus rupestris*) (text-fig. 17), also from

Bushmanland, and a number of small rodents, most of which belonged to species new to the Society's list. After drawing attention to certain interesting morphological points connected with the group of Insectivora to which Elephant-Shrews belong, and remarking that the Society had never previously exhibited

Text-fig. 16.



Common Elephant-Shrew (*Macroscelides proboscideus*).

Text-fig. 17.



Rock Elephant-Shrew (*Elephantulus rupestris*).

specimens of the family Macroscelididae, Mr. Pocock pointed out that in their general appearance and behaviour these animals much more closely resembled Mouse-like rodents than Shrews, on account of the length and texture of the fur, the prominence and size of their staring eyes and of the pinna of the ear, the

only feature that recalled the Shrew being the long, cylindrical, twitching snout. They were also quite like rodents in their quadrupedal gait, the ground being traversed by the ordinary running action or by lightning-like leaps from point to point. They did not raise their fore-quarters from the ground more frequently than is the custom with typical rodents, and were never seen to hop on the hind legs alone, like Jerboas and Kangaroos, as they have been declared to do in some natural histories.

In appearance the two examples of *Macroscelides proboscideus* differed considerably from the one representative of *Elephantulus rupestris*. In the former the eyes were smaller and the ears more widely separated and more concealed in the hair of the sides of the head. In *Elephantulus rupestris* there was a conspicuous light ring round the large eye, the ears were more erect, and separated by a much narrower space on the top of the head. It was noticeable, too, that, whereas the Rock Elephant-Shrew lay hidden beneath a heap of hay during the daytime, the two Common Elephant-Shrews preferred to huddle together in the open part of the cage, evincing a dislike to push beneath the hay and refusing to remain under it when it was placed over them. The differences between the living animals, indeed, quite bore out the view, based upon the structure of the skull, that the two species belonged to different genera.

PAPERS.

10. The Freshwater Crayfishes of Australia.

By GEOFFREY SMITH, M.A., Fellow of New College, Oxford*.

[Received October 20, 1911 : Read November 21, 1911.]

(Plates XIV.-XXVII.† and Text-figure 18.)

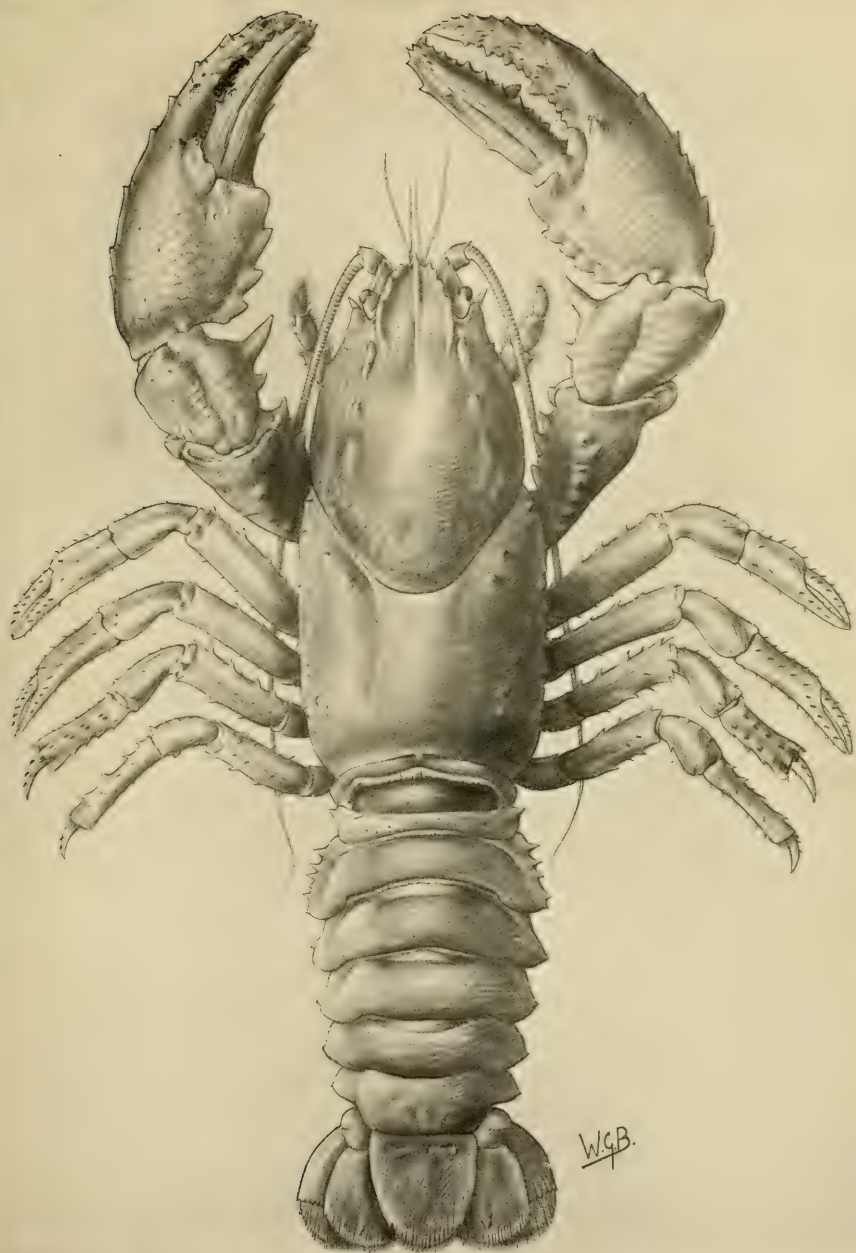
I. Introduction.

The study of Freshwater Crayfishes has been distinguished by the labours of Huxley; the detailed work of Ortmann and Faxon has made us acquainted with the North-American species of *Astacus* and *Cambarus*, and Faxon has reduced the South-American genus *Parastacus* and the New Zealand *Paranephrops* to order, but what Huxley wrote in 1879 concerning the Australian Crayfishes, "that their nomenclature requires thorough revision," is almost as true to-day as thirty years ago.

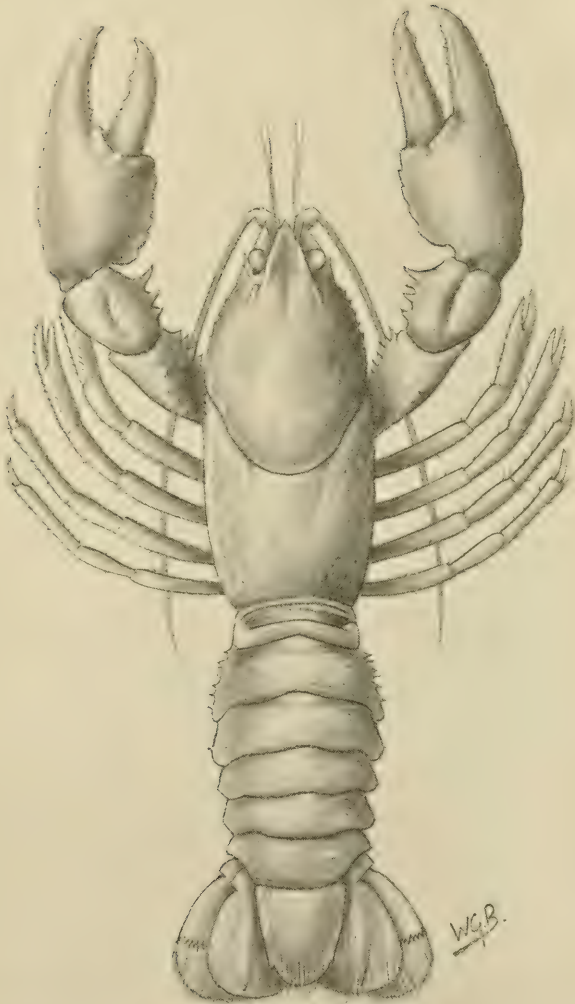
The following memoir does not pretend to be an exhaustive monograph of the anatomy or of the systematic classification of the Australian Crayfishes, but by publishing the series of accurate

* Communicated by the Secretary.

† For explanation of the Plates see pp. 170-171.



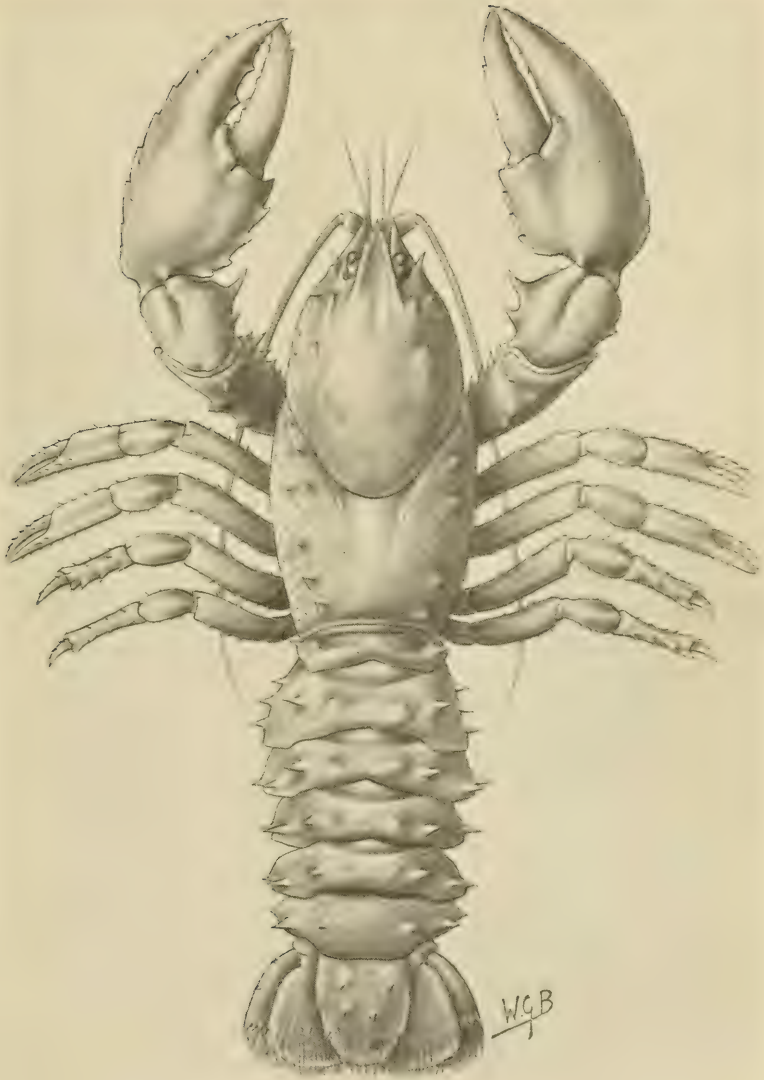
ASTACOPSIS FRANKLINII. ♂.



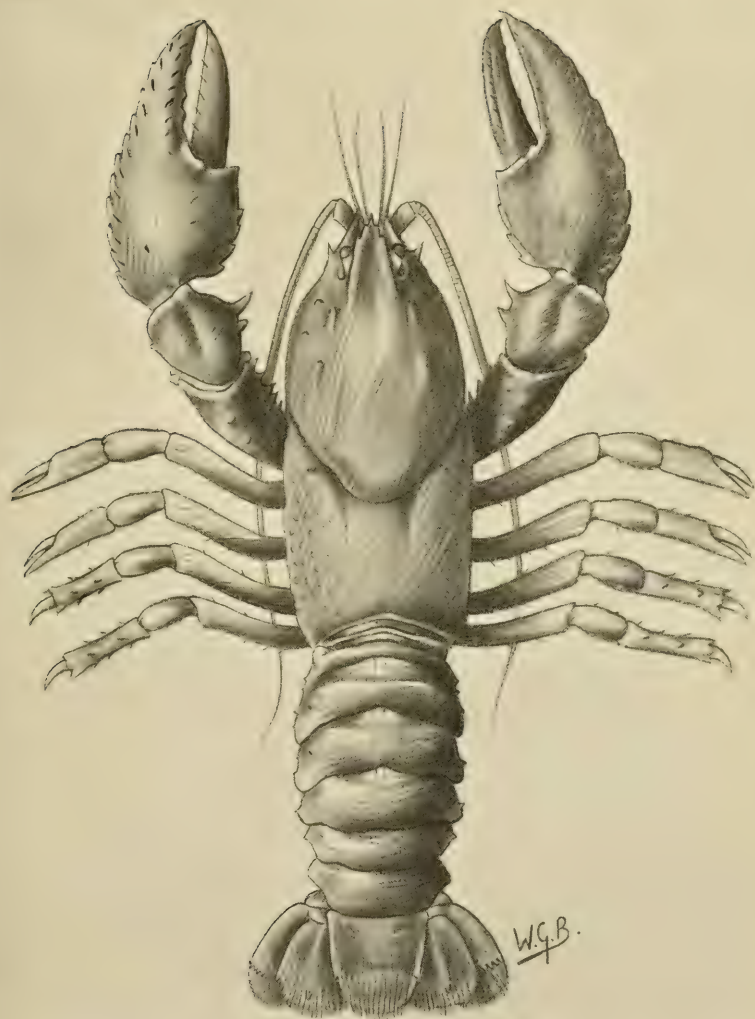
ASTACOPSIS FRANKLINII, ♀



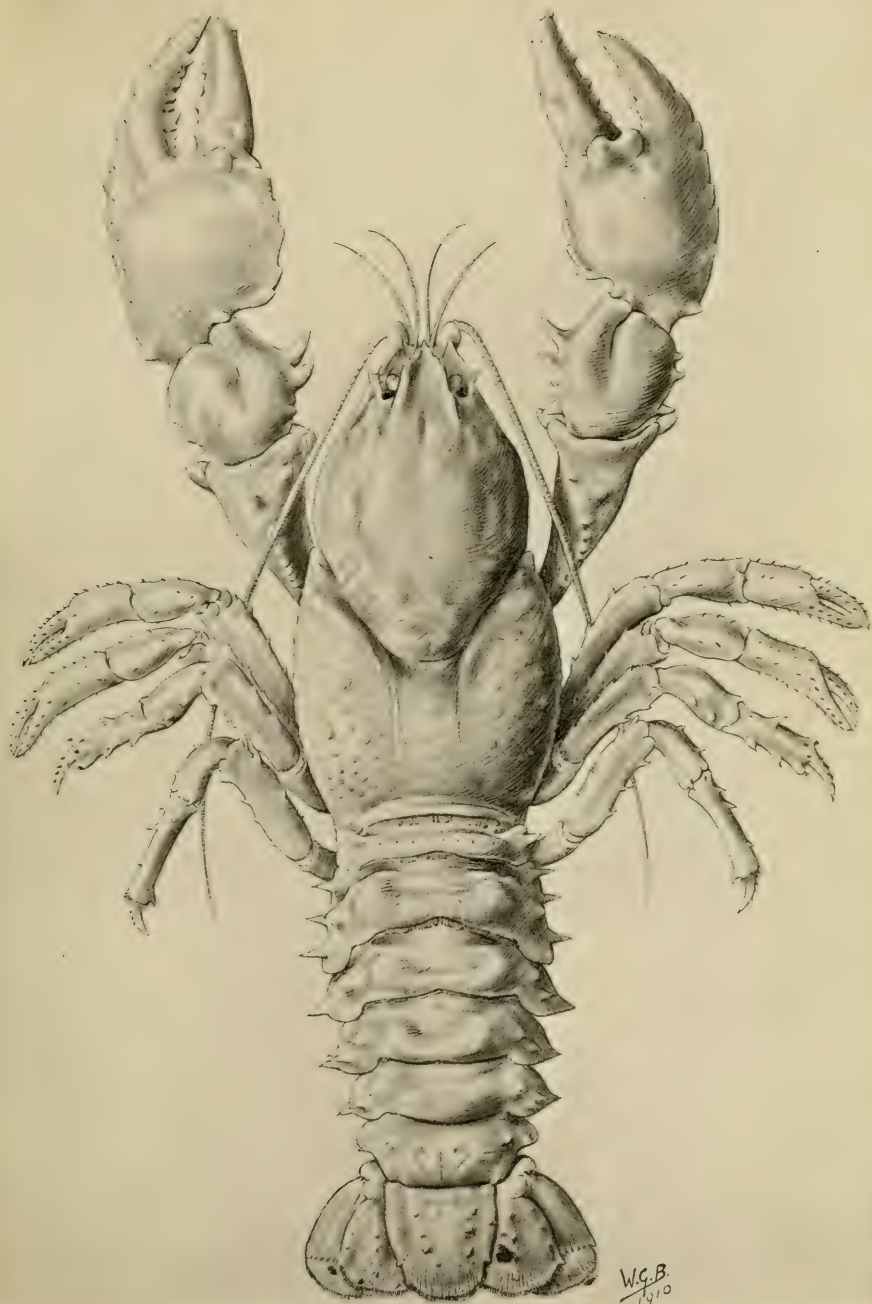
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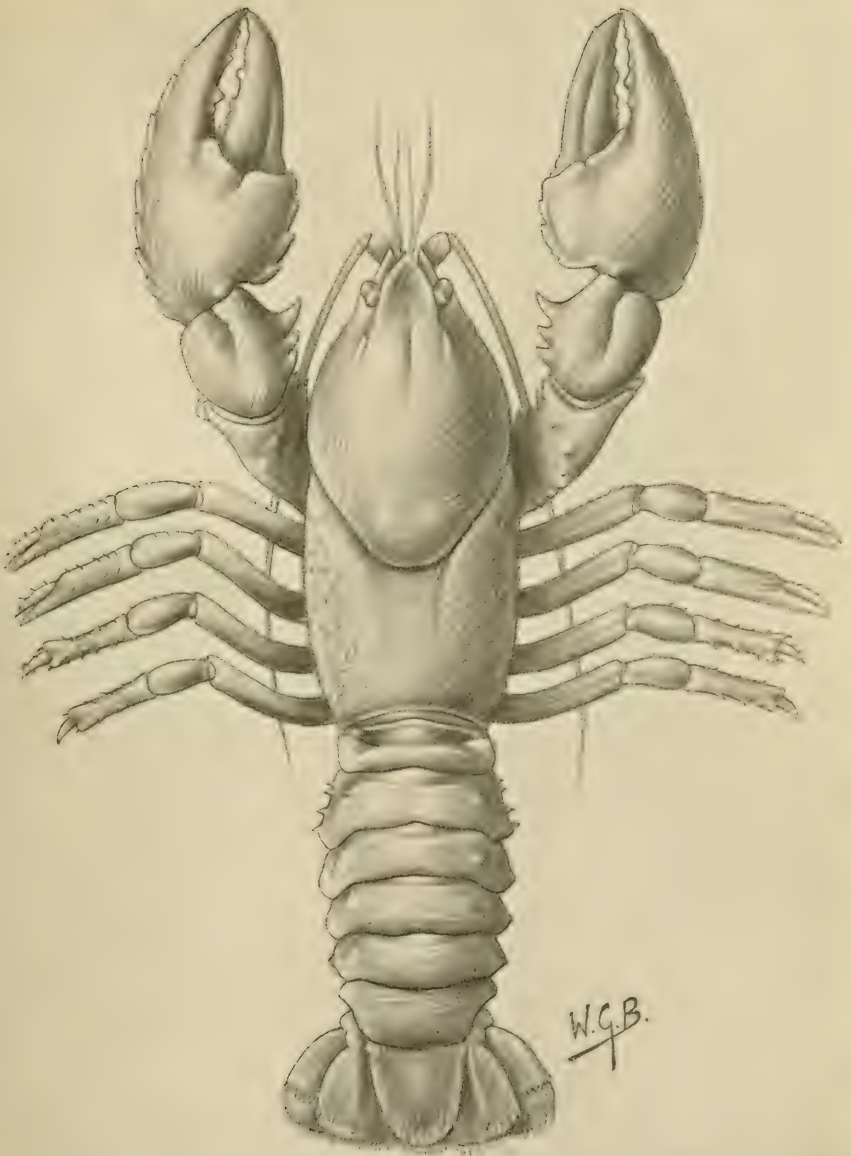
ASTACOPSIS SERRATUS. ♀.



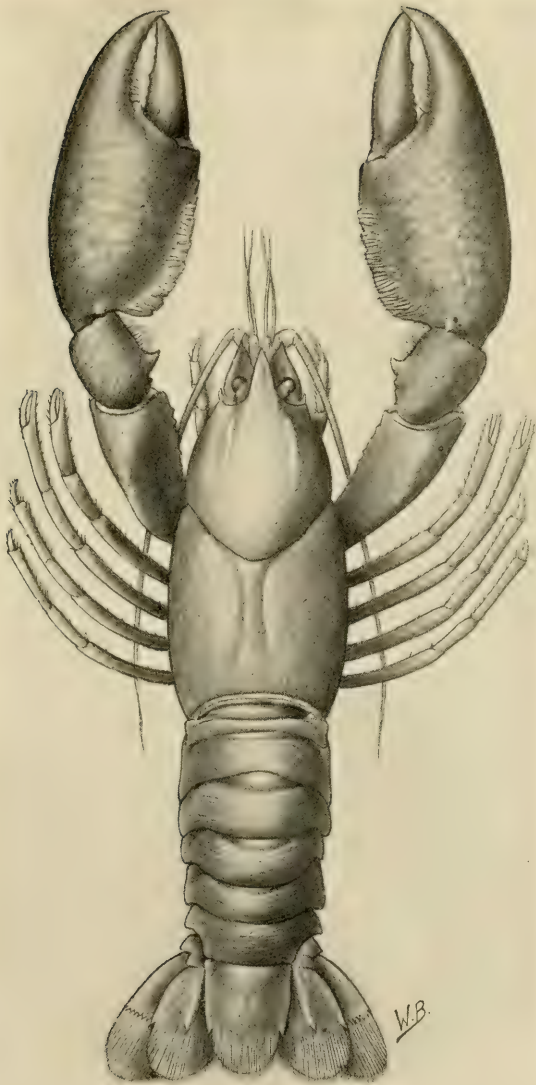
ASTACOPSIS SERRATUS. ♂.



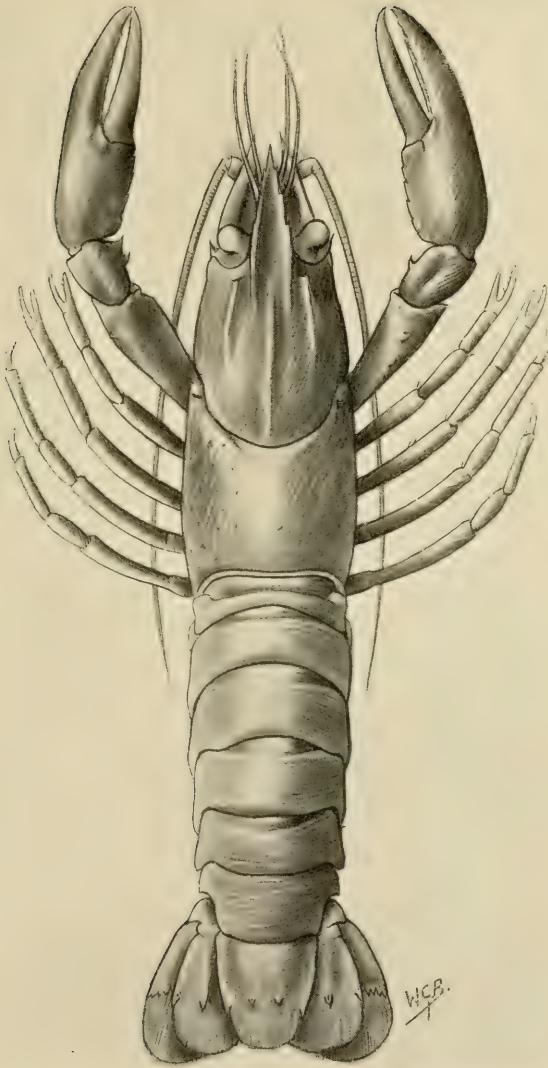
ASTACOPSIS KERSHAWI. ♂.



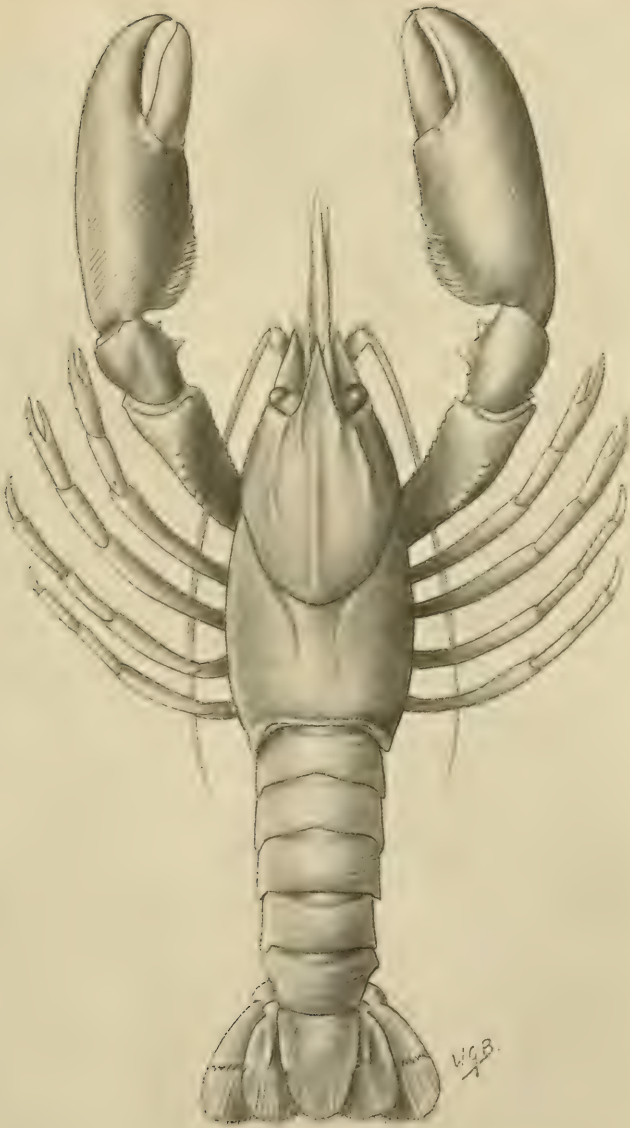
ASTACOPSIS KERSHAWI. ♂.



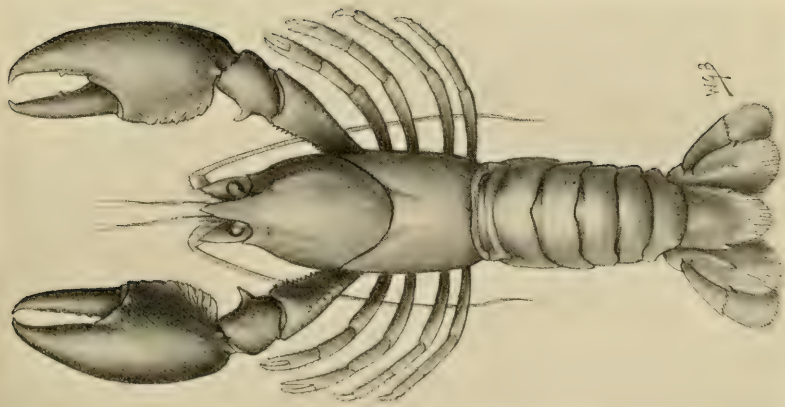
PARACHÆROPS BICARINATUS. ♂.



CHÆROPS TENUIMANUS. ♂.

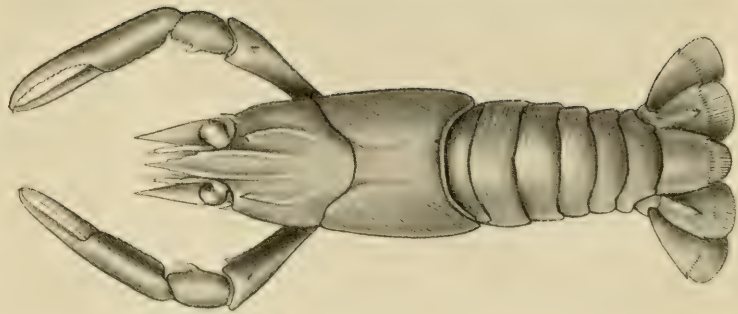


CHÆROPS QUINQUECARINATUS. ♂.

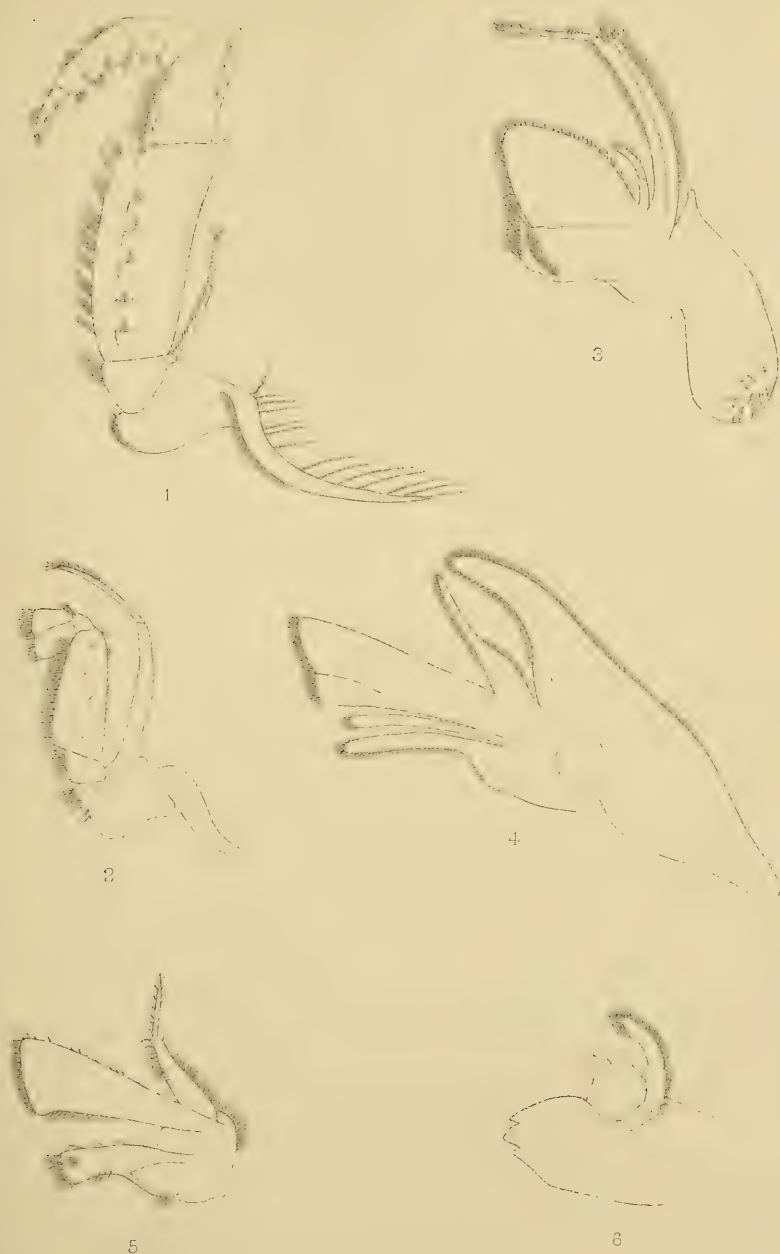


2

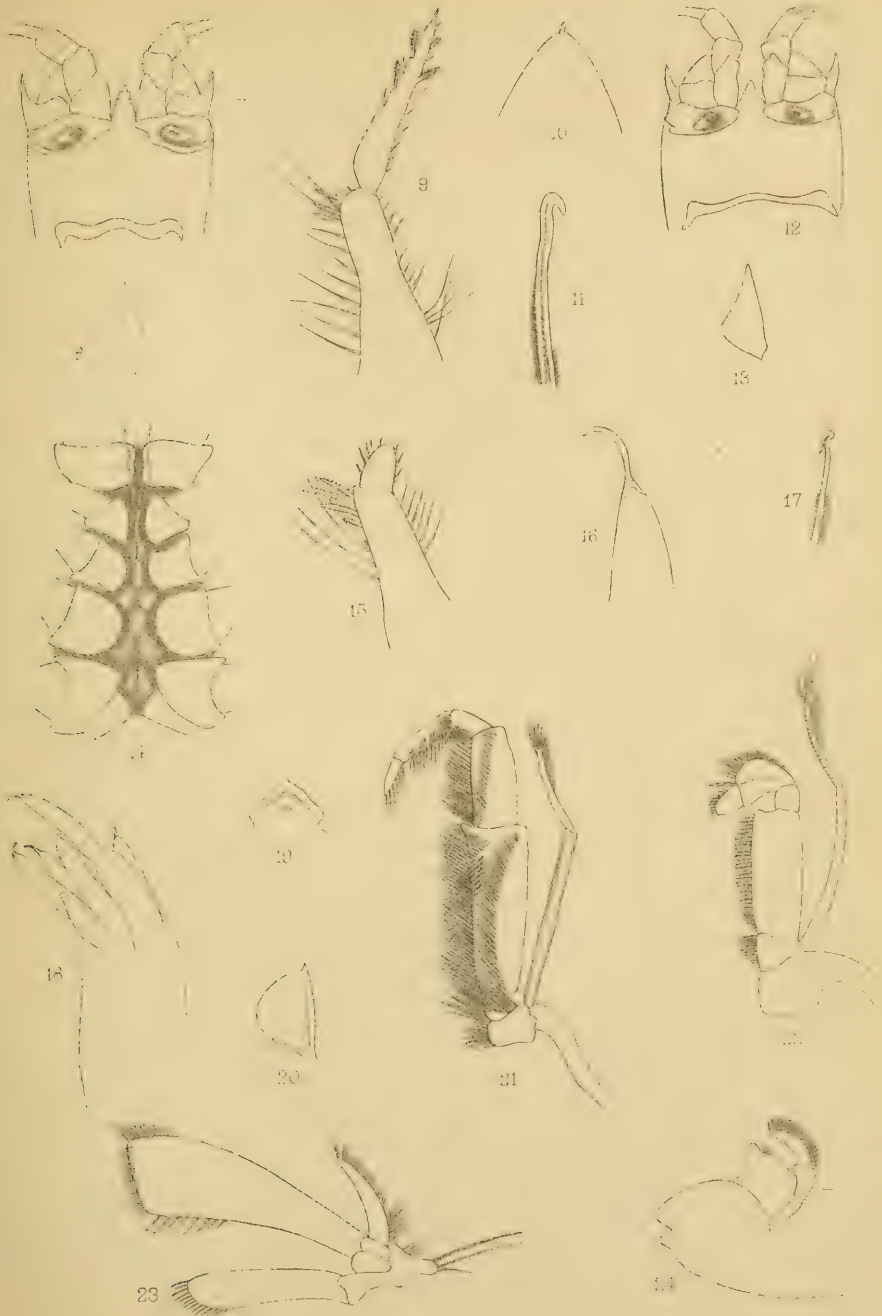
1. CHÆROPS QUADRICARINATUS ♂. 2. C. INTERMEDIUS. ♂.



1.

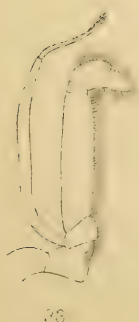
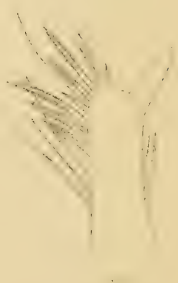
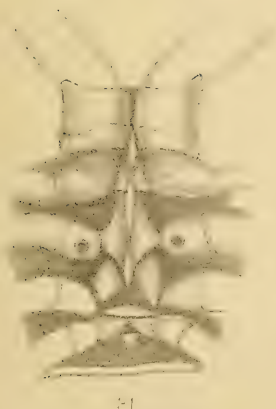


West, Newman lith.



West, Newman lith.

7-11. *ASTACOPSIS FRANKLINII*. 12-14. *A. SERRATUS*.
15-24. *PARACHÆRAPIS BICARINATUS*.



West, Newman lith.

25-29. CHÆRAPS QUINQUECARINATUS. 30. C. TENUIMANUS.
31-33 C. QUADRICARINATUS. 34. C. INTERMEDIUS.

and beautiful drawings made by Mr. W. G. Browning under my direction, illustrating the forms and chief varieties of all the known species, by arranging these species in systematic genera according to their structural affinities, by recording, as far as is known, their geographical distribution, and by indicating the light which they throw upon the geographical problems of Australia, it is hoped that a secure foundation may be laid on which local naturalists can build. In this memoir, only the Freshwater forms are dealt with, comprising the genera *Astacopsis*, *Chærops*, and *Parachærops*, the treatment of the land-Crayfishes of Australia included in the genus *Engæus* being postponed to a future paper. These land-Crayfishes, which are a highly specialised group, probably derived from the freshwater form *Parachærops bicarinatus*, are confined in their distribution to the Victorian Highlands, Gippsland, and Tasmania.

The material on which this memoir is founded was in part collected by myself in Tasmania and Australia during my visit to those countries in the years 1907-8, but by far the largest number of specimens are derived from the very fine collection belonging to the Melbourne Museum, which Professor Baldwin Spencer entrusted to me for description. This collection, which has been gradually accumulated during twenty years by the efforts of a number of Victorian naturalists, especially Mr. Kershaw and Mr. Fulton, is particularly representative of Victorian forms, though specimens from other States are not altogether absent. I have been able to supplement this collection by specimens from New South Wales, through the kindness of Professor Haswell, from Western Australia, through Mr. Woodward of Perth, and from New Guinea, through Dr. Gestro of Genoa.

It appears probable that as the population of Australia increases, the Freshwater Crayfishes might assume as much importance, as an article of food, as the lobster in America or England. There is no true lobster in the Australian seas; its place is taken by a form allied to our Rock Lobster (*Palinurus*), which is altogether inferior as an article of diet. In the first place, it possesses no large claws and the flesh is altogether coarser than in the lobster. The Australian Freshwater Crayfishes, on the other hand, are, on the whole, superior in flavour and texture to our marine lobsters. Several of the forms, notably *Astacopsis serratus* of the Murray River and *A. franklinii* of the North-Tasmanian streams, attain a very large size indeed (Pls. XIV., XVI.), the body reaching a foot in length and the whole animal weighing as much as eight or nine pounds, thus rivalling a fine lobster. These animals not very frequently reach the Melbourne market, and the Tasmanian Crayfish, which is the finest of all, is, I believe, only occasionally caught and eaten by settlers in the bush or a few prospectors. The labour of obtaining these large Crayfishes, for they are not very abundant, has hitherto prevented their becoming an article of commerce. It would probably be

practicable to farm these animals artificially in ponds supplied with running water, such as are used at trout-hatcheries. In the case of the marine lobster this is impossible, since the young hatch out as larvæ which at first live a pelagic existence; but this difficulty is absent from the culture of the Freshwater Crayfish, since the young leave the egg in a condition similar to the adult and pass a certain amount of time after hatching attached to the swimmerets under the tail of the parent. Much work would have to be done upon the habits, food, rate of growth, etc., before the undertaking could be placed upon a practical footing, but the enquiry would be well worth undertaking. It may be suggested that the best form for experimenting with would be the large Tasmanian Crayfish (*Astacopsis franklinii*), which occurs in the neighbourhood of Launceston, and in this town there is already a Government trout-hatchery which has been very successful. One further suggestion may be made: the Freshwater Crayfish industry in Germany, Russia, France, and England has from time to time been seriously damaged and in places extinguished by the occurrence of a plague, probably of bacterial nature; it would therefore be well to investigate the parasites of the form to be cultivated and the best means of protecting it against bacterial diseases.

There is a curious fact connected with the occurrence and nature of the large Crayfishes of Australia and Tasmania. The genus *Astacopsis* is represented by three distinct species, each of which occurs under two forms, a large and a small, which appear to occupy different areas of distribution.

Thus in Tasmania there is the large *A. franklinii* (Pl. XIV.), which is found only in the streams on the north and north-west coast, near their entrance to the sea, and in these situations it appears impossible to obtain small specimens. The small Tasmanian Crayfish (Pl. XV.) (var. *A. tasmanicus*), which cannot be separated from the large form by any important characters, save that of size, occurs in the mountain streams of the southern and central part of the island, where it breeds, but never grows to more than about five inches in length. Parallel facts occur in *A. serratus* (Pl. XVI.), which occurs as a large form in the Murray and Paramatta Rivers but is represented by smaller, less spiny forms further inland (Pls. XVII., XVIII.). *A. kershawii* has a large form in the Moe River of Gippsland (Pl. XIX.) and a small form in the Narracan (Pl. XX.) and smaller streams.

The most obvious explanation of this phenomenon is that the large form, *e. g.* the large Tasmanian Crayfish, really does breed in the north coast streams and that its young stages in growth are passed there and could be found by assiduous search. The only other alternative is that the young of the large form are always destroyed near the mouths of the rivers by Blackfish and other predaceous forms which prey upon them, and that their numbers are recruited by a few individuals of the small mountain forms which find their way from the inland streams to the mouths

of the rivers. The species, in this case, would be always recruited from the small inland forms. Whether this suggestion holds good or not, the problem of why small individuals have not hitherto been found in the streams where the large Tasmanian and Murray River Crayfishes occur requires settling one way or the other.

Since this question at present remains open and I have found it impossible to discover morphological points of any value between the large and small forms of these species, I have not treated them as distinct species. This leads to the inclusion under one specific name of the very widely distributed form *A. serratus*, which occurs in the Murray River and its tributaries, in the Victorian rivers such as the Yarra, Plenty, and Bunyip Rivers, again in the Paramatta River at Sydney and in the Blue Mountains. This is a truly immense range for a species such as this to occupy, which, so far as we know, never forsakes the water for any length of time and has been presumably slowly distributed by the slow alteration and communication of different river-systems. Many of these widely separated communities of Crayfishes cannot have interbred for centuries, almost for geological periods, and yet they have retained the common specific characters with remarkable constancy. It is true that an immense range of variation in size and in the degree to which the spines are developed is met with in these local groups, but these characters show graduations, and the development of the spines is so variable, being often asymmetrical on the two sides of one specimen, that they do not offer constant specific characters for separating the various groups. It appears to me certain that it is impossible to separate the large Paramatta Crayfish from the large Murray River form, and yet these two large rivers belong to two different systems, their nearest point of approach being in the Blue Mountains on different sides of the watershed. With the material at my disposal I am unable to split up these various local specimens of *A. serratus* into a number of subspecies, although I do not wish to prejudice the work of some future investigator who, with more material at command, may feel himself competent to do so.

II. *The Relationships of the Australian Crayfishes and their Geographical Distribution.*

The Crayfishes of Australia, Tasmania, and New Guinea belong, in common with those of New Zealand, South America, and Madagascar, to the family Parastacidae, which differs from the Crayfish family of the Northern Hemisphere, the Astacidae, in a number of important characters which were first pointed out clearly by Huxley. The diagnostic features of the Parastacidae given by Huxley (P. Z. S. 1878, p. 775) are as follows :

"The podobranchiae are devoid of more than a rudiment of a lamina, though the stem may be alate. The podobranchia of the first maxillipede has the form of an epipodite; but in almost

all cases it bears a certain number of well-developed branchial filaments.

"The first abdominal somite possesses no appendage in either sex; and the appendages of the four following somites are large. The telson is never completely divided by a transverse suture.

"More or fewer of the branchial filaments are terminated by short hooked spines; and the coxopoditic setæ, as well as those which beset the stems of the podobranchiæ, have hooked apices."

The Astacidae possess the converse of these diagnostic characters.

The Astacidae and Parastacidae, the one family occurring in the Northern Hemisphere, the other in the Southern, are therefore separated by important characters, and it is very probable that they have been independently evolved from marine lobster-like ancestors which already differed in these characters before they took to a freshwater life.

The occurrence of Parastacidae in Australia, New Zealand, and South America, with an aberrant genus (*Astacoides*) in Madagascar—that is to say, in countries which are now separated by wide stretches of ocean—is a striking fact in geographical distribution, but it does not stand alone, the distribution of many freshwater fish, crustacea, molluscs, etc., having a similar character in the Southern Hemisphere.

These facts, taken in conjunction with geological evidence, have led many naturalists to assume a much greater extension of the Antarctic Continent in past times which is supposed to have been connected with South America, Australia, and New Zealand, and possibly at a very remote period with Madagascar, thus permitting the migration of land and freshwater animals to and from those countries. In the case of the Parastacidae the only alternative theory is that the South-American, Australian, and New Zealand genera have been independently derived from some common marine ancestor.

Our concern here, however, is not so much with the origin of the Parastacidae in the remote past, but with the inter-relationships of the Australasian genera and their probable evolution and migrations.

We can distinguish four genera of Australasian Crayfishes—*Astacopsis*, *Parachærops*, *Chærops*, and *Engæus* (the last-named genus we will consider as a single entity, though it may be found convenient hereafter to split it up into several subgenera).

The members of the genus *ASTACOPSIS* are characterised by the development of spines or tubercles upon the body and limbs, and by certain features in the gills and appendages which are fully set forth in the diagnosis of the genus on p. 154. They inhabit swift-moving streams and rivers; they are not found in ponds and water-holes, and they are not known to forsake the water for any period of time. Their distribution is as follows:—In Tasmania there occurs *A. franklinii* (Pls. XIV., XV.), the largest Crayfish in the world. It is confined to the rivers and streams upon the

north and west coasts. In the highland streams of the south and centre a small form occurs (var. *tasmanicus*) which may or may not be reckoned as a separate species (see p. 156). *A. serratus* (Pls. XVI.–XVIII.) occurs as a large form in the Murray River and in the Paramatta River at Sydney. As a small or medium-sized form it occupies the Victorian Highlands, and as a small form it also occurs in the Blue Mountain streams. *A. kershawi* (Pls. XIX., XX.), which is, in many respects, intermediate between the above two species, lives in a few Gippsland rivers, thus occupying also an intermediate geographical station. The genus *Astacopsis* therefore runs from the mouth of the Murray River southwards to Gippsland and Tasmania and up the east coast to Sydney. Its centre of distribution would appear to be the Murray River and its tributaries, and it is confined to the south-eastern corner of Australia and to Tasmania, where the climate is temperate and clear swift-running streams are abundant.

Text-fig. 18.



Map of Australia showing areas of distribution of Crayfishes.

The genus *CHÆRAPS* (see p. 165 and Pls. XXII.–XXIV.), although departing in many important features from *Astacopsis*, yet shows a trace of agreement with this genus, especially in the

fact that the last posterior arthrobranch is not rudimentary. Its members inhabit running water, and they are confined in distribution to the west and north coasts and to New Guinea, being entirely absent from the southern and eastern districts occupied by *Astacopsis*. In the south the arid coast-line, fringing the Great Australian Bight, constitutes a wide and insurpassable barrier between the genera *Astacopsis* and *Chæraps*. On the east coast *Chæraps* is absent and *Astacopsis* does not appear to occur much north of Sydney.

The species *C. intermedius* (Pl. XXIV. fig. 2) from Western Australia is of great interest, because it forms a perfect transition to the genus *Parachæraps*. *C. intermedius* retains the diagnostic features of a *Chæraps*, but it presents a remarkable approach in general facies and in a number of points to *Parachæraps bicarinatus*.

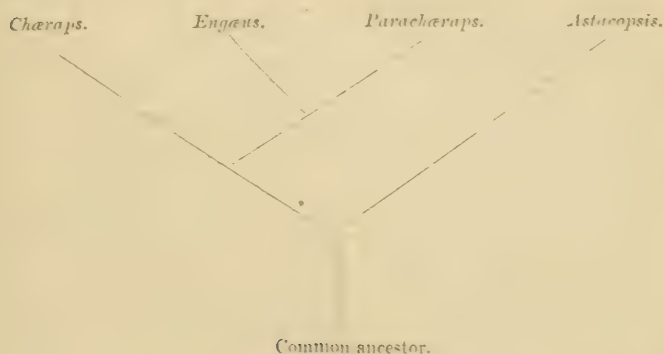
The genus *PARACHÆRAPs*, consisting of the single species *P. bicarinatus* (Pl. XXI.), is closely allied in all its features to *Chæraps*, and the alliance is made more obvious by the existence of the before-mentioned *C. intermedius*, which may reasonably be regarded as the ancestral form from which *P. bicarinatus* has been derived. *P. bicarinatus* is the most widely distributed Crayfish on the Australian continent, being the only form which penetrates into the interior of the continent. It is, in fact, universally distributed all over the continent, occurring with *Chæraps* in the west and north and with *Astacopsis* in the south and east. It does not occur in Tasmania or in New Guinea. The relationship of this genus and species is obviously with the western *Chæraps*, and it is also equally certain that it is a secondary derivation from *Chæraps*, which has been able to spread across the deserts eastwards and invade Victoria in the south by becoming adapted to live under semi-desert conditions. The alternative supposition, viz. that *Parachæraps* is the ancestral form and has given rise to *Chæraps*, is clearly negatived by the impossibility of thus accounting for the fact that, although it ranges as a continuous species all over the continent, it should have given rise to several species of *Chæraps* only in the west. It would be difficult also on this supposition to account for the fact that *Chæraps* differs less from *Astacopsis* than *Parachæraps* does. In fact, if we take the now almost universally distributed *Parachæraps* as representing the ancestral form of Australian Crayfish, the entire isolation, both structurally and geographically, of *Astacopsis* and *Chæraps* becomes unintelligible.

It is worthy of notice, also, that *Parachæraps* apparently does not occur either in New Guinea or Tasmania, and, although stress cannot be laid on this fact, it is possibly another indication of the modern origin of *Parachæraps*, after the separation of New Guinea and Tasmania from the mainland of Australia.

The genus *ENGELS*, comprising the land-burrowing Crayfishes, which have gone a step beyond *Parachæraps* in their independence of water, are confined to Victoria, Gippsland, and Tasmania. From

their habits and anatomical structure they have probably been derived directly from *Parachærops*, some of the species graduating very perfectly into the latter genus. The burrowing land-Crayfishes are therefore the most modern product of all. Although it is not my intention to give any description of the genus *Engæus* in this paper, certain of their characters may be mentioned which point to their high degree of specialization. Their whole appearance and form are very different from the other Crayfishes, the thorax being extremely deep dorso-ventrally, a character which is correlated with the very great size of the gastric mill. The abdomen is much reduced in size. Certain of the species show a peculiar reduction in the gill-formula, the last pleurobranch being entirely absent, while in some species the exopodite of the maxillipede is completely absent. The body is entirely free from spines or ridges.

The above survey and an examination of the diagnoses of the several genera afford a remarkably clear picture of the evolutionary relationships of the genera described, which we may represent in the form of a table, thus:—



We may attempt to reconstruct also the means by which these genera have reached their present geographical distribution. The outstanding fact is clearly the complete isolation in structure and distribution of the western *Chærops* from the eastern *Astacopsis*. This sharp distinction between a South-eastern and a North-western Australian fauna does not apply only to Crayfishes, but is practically universal, and in looking for a cause the attention of naturalists has been called to the existence in Central Australia of Cretaceous deposits, which are held to indicate the existence of a sea in Cretaceous times dividing Australia into a western and an eastern island. We may therefore start with the hypothesis that the separation and divergent evolution of *Astacopsis* and *Chærops* dates from the separation of Eastern and Western Australia by the Cretaceous sea. It would appear that, with the

filling in of this sea and the junction of the eastern and western islands, no feasible passage was formed by means of which the eastern *Astacopsis* could invade the territory of the western *Chærap*s or *vice versa*. The nature of this early barrier is uncertain, but when once the desert condition was established, the central deserts have constituted a barrier against a direct eastern or western migration: on the south-west coast the desert and semi-tropical region of the Australian Bight prevents a northern passage of *Astacopsis* into the territory of *Chærap*s, while to the north-east the semi-tropical coastal streams do not appear to have been colonized either by *Chærap*s moving southwards or *Astacopsis* migrating northwards. *Astacopsis*, in fact, remains a typically temperate genus, *Chærap*s a semi-tropical or tropical one, and the barrier of temperature seems to determine the distribution of these two forms with complete rigidity.

An offshoot from *Chærap*s, however, viz. *Parachærap*s *bicarinatus*, on the filling in of the Cretaceous sea, has gradually extended its range from the west eastwards, invading the central districts of Australia and penetrating thence southwards and eastwards so as to become almost coterminous in distribution with *Astacopsis*. In the very centre of the *Astacopsis* distribution, viz. in Victoria, *P. bicarinatus* is particularly abundant, and here it has given rise to the burrowing land-Crayfishes, *Engæus*, whose headquarters are in this region. If it is true that *P. bicarinatus* does not occur in New Guinea or Tasmania, the view that this form is of comparatively recent origin is amply confirmed, the date of its origin and migration being fixed as subsequent to the separation of New Guinea and Tasmania from the mainland in Tertiary times. We are, however, here confronted with a difficulty, since, although *P. bicarinatus* apparently does not occur in Tasmania, one or two species of *Engæus*, which we must hold to be derived from *P. bicarinatus*, are common in Tasmania. The habits, however, of *Engæus* are peculiar, and it is quite possible that individuals of this genus have been carried across Bass's Straits from Gippsland in floating tree trunks, at the roots of which the "land-crabs" frequently make their burrows.

Without unduly pressing this hypothesis, it nevertheless offers an explanation of the curious fact of the occurrence of *Engæus* in Tasmania and the absence of its parent form, *P. bicarinatus* from that island.

The occurrence of *A. kershawi* in Gippsland, related by many of its features, *e. g.* the absence of spines on the abdomen and the truncated shape of the rostrum, to *A. franklinii* in Tasmania, cannot be passed over without reference. It is apparently confined to Gippsland, but it is surrounded and in close contact with the much more widely distributed *A. serratus*. Its relationship to the Tasmanian form indicates a close connection at some not very remote time between Gippsland and Tasmania, a connection which may be detected in the similar geological and

physiographical characters of these two countries. It seems probable that when the two countries were in actual continuity they together formed a zoological district with many features in common, distinct from the surrounding countries of Victoria and New South Wales.

By the foregoing lines of argument we are able to establish on a secure basis the general course of evolution and the routes of dispersal of the Parastacine Crayfishes of Australia. We are able to establish with certainty that the widely distributed *Paracharaps bicarinatus* is a comparatively recent derivation from the Western-Australian *Charaps*, and that the land-Crayfishes, *Engæus*, are a still more modern derivative from *Paracharaps*. We are left, therefore, with *Charaps* and *Astacopsis* as the two primitive representatives of Australian Crayfishes, which, both by their complete isolation from one another and by their wide distribution, betray a great antiquity. The question as to which of these two primitive genera is the most primitive and represents to the greatest extent the original ancestor of the group is a very obscure question. We may, however, make some suggestions for the solution of this problem.

Since Crayfishes in general are emphatically not tropical forms, and since the Australian Crayfishes are only represented in Northern Australia by a single species, *C. quadricarinatus*, it is certain that this form is only a northern straggler, and that New Guinea and North Australia are not the centre of distribution of the group. Granted that the centre of distribution is somewhere in the south of the continent, have we any light to guide us in choosing between *Charaps* or *Astacopsis* as occupying most nearly the original area of distribution? The genus *Astacopsis*, on the whole, now lives under conditions more generally characteristic of Freshwater Crayfishes than *Charaps*. It is characteristic of cooler regions and is particularly abundant in mountain streams of great rapidity and clearness; while the western *Charaps* inhabits rivers, more sluggish and clouded in nature, which rather fitfully irrigate a parched country. It seems that *Charaps* is already in the grip of those circumstances attendant on a lack of water which have finally resulted in the production of such specialized forms as *Paracharaps* and *Engæus*. This is no more than a suggestion, but if it is true we are led to the conclusion that the more southern *Astacopsis*, inhabiting the temperate and well-watered mountainous regions of South and South-eastern Australia, retain to the greatest extent the original characteristics and distribution of the ancestral form. If this is so, and if the Bassian Subregion is really the centre of distribution of the Australian Parastacidae, we may perhaps include these animals in the array of alpine plants and animals characteristic of this region, which were probably once distributed across the Antarctic Continent and reached their present distribution in South America, South Australia, and New Zealand by this means.

III. *Systematic Account of the Genera and Species of
Australian Parastacidae.*

Genus *ASTACOPSIS* Huxley (P. Z. S. 1878, p. 764).

Arthrobranch of last leg but one not rudimentary or even much reduced. Ala of podobranchs small and inconspicuous. Short and stout hooks only present at the end of a few branchial filaments fringing the stem of podobranchs (Pl. XXVI. fig. 10), being absent in all other gills.

Hooked setae on coxopodites and on gill-stems not very sharply recurved (Pl. XXVI. fig. 11).

Mandibles with three prominent teeth and smooth lower ridge (Pl. XXV. fig. 6).

First maxilla with endopodite consisting of base and distinct flagellum united on to it (Pl. XXV. fig. 5; Pl. XXVI. fig. 9).

Second maxillipede with penultimate segment bearing an upper lobe, which projects forwards as far as terminal segment (Pl. XXV. fig. 2).

Third maxillipede with serial row of bristles on outer face of third and fourth segments, and a sparse fringe of bristles on inner face. Exopodite does not equal third segment in length (Pl. XXV. fig. 1).

Great chela with the carpus rather short and stout; much tuberculated, with a row of tubercles on its outer border as well as on the inner (Pls. XIV.—XX.).

Succeeding legs with terminal and subterminal joints well provided with pencils of bristles. Opening of vas deferens situated on a short simple papilla.

The lateral keels of rostrum are spiny or tuberculated. Lateral carina on carapace is also spiny or tuberculated. Carapace and branchiostegites tuberculated or spiny. The sternal keel is depressed and blunt (Pl. XXVI. fig. 14).

The first abdominal segment carries lateral spines; the succeeding segments are spiny, tuberculated, or setose.

The membranous portion of telson and uropods is short compared to the upper calcified portion, and the median spine on the endopodites of the uropods is, in consequence, situated distally.

ASTACOPSIS FRANKLINII. (Pls. XIV., XXV., & XXVI., figs. 7–11.)

The Large Tasmanian Crayfish.

(Gray, *Eyre's Journals of Expeditions of Discovery into Central Australia*, i. p. 409, 1845.)

The rostrum is rather broad and tumid, and ends in a short median spine; the lateral keels are rounded, and each keel carries four or five blunt spines or tubercles.

On the carapace immediately lateral to the posterior outer border of the rostral carina, a tubercle, often double, is present, and posteriorly in a line with this tubercle is another rounded tubercle, and behind this again a rounded boss. The disposition of these tubercles is subject to some variation. Laterally and anteriorly, the cephalothorax has a few blunt spines and tubercles, and there are numerous blunt tubercles on the branchiostegites.

Ventrally the interantennal spine is rather long and narrow, and not produced laterally at the base. The chitinous margin of upper lip has large lateral arches and a small median arch (Pl. XXVI. fig. 7).

The inner border of the antennal scale widens rather suddenly at the base of the terminal spine (Pl. XXVI. fig. 8).

The sternal keel is of the usual *Astacopsis* type, but is sharper than in succeeding species.

The first abdominal segment bears laterally a prominent forwardly directed spine.

The second abdominal segment has a varying number (4-7) of small sharp spines on each lateral border.

The succeeding abdominal segments are smooth, but laterally each segment is produced into a small sharp spine, often with another smaller spine just above it.

The exopodite of the uropod has a row of teeth between the hard and membranous portions, which graduates internally into a row of bristles. The endopodite has a small spine close to the distal border in the middle line.

The telson has two lateral serrations, but is otherwise smooth.

The great chela has the pincer studded with tubercles and a few brushes of setæ. Two tubercles in the pincer, one on the upper or outer and one on the inner pincer, are greatly enlarged, especially in the larger specimens. The inner edge of the carpopodite has three or, at most, four serrations. The surface of the carpopodite is not greatly pitted.

The two anterior walking legs have only a few spines, but numerous brushes of bristles. The two posterior legs have more numerous spines, which are not very long or conspicuous.

The colour is uniform dark green.

The largest specimen obtained by me weighed just under eight pounds, and measured 16 inches from rostrum to telson. Small specimens less than 8 inches are very rarely obtained, and have not been seen by me.

Localities.—Several specimens were taken by me from the Brid and Muddy Creek, Bridport, Tasmania—the latter stream being a very small muddy rivulet. They are also reported from numerous streams and rivers along the north coast, and from the Gordon River on the west coast, but they are unknown from the south, east, or central districts of Tasmania.

The Small Tasmanian Crayfish, Var. *TASMANICUS*. (Pl. XV.)

(Erichson, Archiv für Naturgeschichte, 12 Jahrg. p. 94.)

This species (?), which occurs on Mount Wellington and the southern and central ranges of Tasmania, reproduces on a small scale almost all the characters of the large northern and western *A. franklinii*, so that it may perhaps be considered as only a small variety of the large form. The following characters, which may, however, be merely differences due to growth, may be referred to. There is a great reduction of the tubercles upon the carapace and branchiostegites. The upper margin of the carpopodite of the great chela has about six serrations; there is no pronounced enlargement of two tubercles in the pincer. The inner border of the meropodite has about six spines. The surface of the carpopodite is greatly pitted. The spines on the walking-legs are reduced to very minute points.

The colour is green.

The length of fully adult specimens is never more than 5 inches.

Localities.—Streams on Mount Wellington, Tasmania (1907). A small specimen with the tubercles more prominent than usual, measuring 100 mm., from Traveller River, Lake St. Clair, Tasmania (1893). Two small specimens from Zeehan, West Coast of Tasmania.

Remarks on the above two species.—There are, in reality, no distinctive characters, beyond those due to size, by which the above two forms can be separated. The fact, however, that the small and large forms occupy different stations in different parts of the island appears to preclude the possibility of the small specimens being merely not fully-grown individuals of the large form. A most curious fact is that I was unable to obtain the young stages in growth of the large *A. franklinii* in the rivers and streams, where the large individuals were fairly common. The localities from which the large *A. franklinii* have been obtained are invariably in the mouths of the streams near the sea, and in these localities it is impossible, apparently, to obtain small specimens. The small *A. tasmanicus*, on the other hand, is always found inland in mountain-streams, often near their sources. It is therefore within the bounds of possibility that the large *A. franklinii* represents those individuals of the small *A. tasmanicus* which have succeeded in reaching the mouths of the rivers, but that the young which they produce at these situations do not arrive at maturity, owing to the presence of predatory fish, e. g. *Gadopsis marmoratus*. The species would then be entirely recruited from the young of the small form, which breeds up in the mountains. Exactly parallel facts are met with in the other species of *Astacopsis* now to be described. A careful examination of this question should be undertaken by a local naturalist.

ASTACOPSIS SERRATUS. (Pls. XVI. XVIII. & XXVI. figs. 12-14.)

The Murray River Crayfish.

(Shaw, Zoology of New Holland, vol. i. p. 407, pl. iii., 1843.)

Nomenclature.

Names given to Murray River form :

Cancer serratus Shaw, *loc. cit.*

Gray, Eyre's Journals of Expeditions of Discovery into Central Australia, vol. i. p. 409, 1845.

Astacus armatus Von Martens, Ann. Mag. Nat. Hist. ser. 3, vol. xvii. p. 359, 1866.

Astacoides spinifer Heller, Novara Reise, Crustaceen, p. 102, Taf. ix., 1865.

Astacoides serratus McCoy, Prodromus of the Zoology of Victoria, vol. i. pl. 15, 1885.

Names given to Paramatta River and other forms :

Astacopsis spinifer Spence-Bate, 'Challenger' Reports, vol. xxiv. pl. xxviii., 1888. (Large Paramatta form.)

Astacopsis nobilis Dana, United States Exploring Expedition—Crustacea, Part I. p. 526, pl. xxxiii., 1852. (Locality given as New South Wales. A not very clear figure of a 5-inch specimen.)

Astacus australiensis Milne-Edwards, Hist. Nat. Crust. vol. ii. p. 332, pl. xxiv. (Small Paramatta type.)

Astacopsis paramattensis Spence-Bate, *loc. cit.* p. 202, pl. xxiii. (Small Paramatta specimen.)

A. sydneyensis Spence-Bate, *loc. cit.* p. 204, pl. xxiii. (Very small Paramatta specimen.)

Astacoides plebeius Hess, Archiv für Naturg. xxxi. p. 164, Taf. 7, 1865. (From Sydney. Small Paramatta (?) form.)

Rostrum elongated; spines on rostral keel sharp and long; posterior border of keel tumid.

A sharp spine is present on carapace just posterior and lateral to the end of rostral keel, and another sharp spine is present posterior to this and confluent with a rounded boss.

There are a few blunt tubercles and two or three sharp spines on the antero-lateral part of the carapace, and the branchiostegites are not only tuberculated, but carry a superior row of very large spines.

The interantennal spine is rather short and broad, with produced lateral angles at the base (Pl. XXVI. fig. 12).

The chitinous margin of the upper lip has small lateral arches and a large concave median arch (fig. 12).

The inner border of the antennal scale does not suddenly expand at the base of the terminal spine (fig. 13).

The sternal keel is depressed and blunt (fig. 14).

The first abdominal segment has two very large spines on each dorso-lateral margin.

The second abdominal segment has two (sometimes three) smaller lateral and two large dorso-lateral spines on each side.

The next three abdominal segments have two large dorso-lateral spines, and one (sometimes two) small lateral spine on each side.

The sixth abdominal segment carries two small lateral spines or tubercles on each side.

The telson has two (sometimes more, a variable number) median spines.

The number and arrangement of the above spines is sometimes variable and even asymmetrical.

The great chela has two enlarged tubercles in the pincers, both on the biting-edge of carpopodite. The lower external border of the carpopodite has a row of sharp and large spines continued right down to the posterior border. The upper internal border has about five marked serrations. The carpopodite is flattened, and does not carry any tubercles on its other surfaces. The mesopodite has three large spines on its inner border and two on its outer.

The first two walking-legs are nearly free from spines, but the last two carry long and prominent spines, especially on the last joint but one.

Colour (as given by McCoy).—The anterior legs, the middle of the back, and the apices of the spines and tubercles rich creamy white or ivory-coloured; the ground-colour of the other legs, the sides of the carapace, and the abdomen pale Prussian-blue of varying intensity in different individuals, or sometimes mottled with dull olive-green. Semicorneous flexible edges of tail-fin brownish.

Largest specimen obtained measured 10 inches (about 230 mm.); the smallest 7 inches.

Locality of type specimens.—Murray River.

Local Varieties.

FROM VICTORIA.

(a) Bunyip River. . . One specimen, January 1880, measuring 140 mm. It resembles the Murray River form, except that the spines on carapace and branchiostegites tend to be replaced by blunter tubercles, also the dorsal spines on abdominal segments. On second abdominal segment there are four lateral spines on left side, three on the right, thus illustrating the variability and frequent asymmetry of these spines.

(b) Yarra River. Several specimens, 1905. A large specimen (Pl. XVII.), measuring 150 mm., has a single spine on each side of first abdominal segment, three lateral spines on second, and the dorsal spines on abdominal segments clearly marked but reduced. The smaller specimens, about 100 mm. in length, have, in some cases, a single spine on first abdominal segment, in others two; there is a great reduction of dorsal spines on the

abdominal segments. The Yarra River Crayfish has been described and figured by McCoy ('Prodromus of Zoology of Victoria,' vol. ii. pl. 160) as *Astacopsis serratus* var. *yarraensis*, and he refers to its brilliant blue colour, but he otherwise regards it as merely a variety of *A. serratus* from the Murray River.

(c) Kennedy's Creek, a tributary of Curdie's River. Two specimens (1897), one measuring 135, the other 100 mm. Both very similar to above. There are four spines on second abdominal segment in one specimen, three in the other. The dorsal abdominal spines are well marked, but reduced.

(d) Plenty River. One specimen (1896), measuring 160 mm., has two spines on right side of first abdominal segment, one on the left. There are four spines on right side of second abdominal segment, three on the left. The dorsal abdominal spines and those on carapace are rather reduced.

FROM NEW SOUTH WALES.

(e) Paramatta River, Sydney. The *Large Paramatta River Crayfish* has been figured by Spence-Bate ('Challenger' Reports, vol. xxiv. p. 194, pl. xxviii.) under Heller's name of *Astacopsis spinifer*. He regards it, in common with McCoy and others, as identical with the Murray River form. I have not seen the large Paramatta Crayfish, but from the excellent figure given by Spence-Bate I cannot detect any difference between it and the Murray River form.

(f) Paramatta River. The *Small Paramatta Crayfish* described and figured by Spence-Bate (*loc. cit.*) as *Astacopsis paramattensis*. It is about 100 mm. long, and is distinguished from the large form (e) by complete reduction of spines on carapace and abdomen to similarly situated small tubercles. It is, however, very probable that this specimen, coming as it does from the same river as the large form, only represents a stage in growth of the large Paramatta Crayfish. Dana's *A. nobilis* and Milne-Edwards's *A. australiensis* both probably belong here.

A very small specimen (about 50 mm.), described and figured by Spence-Bate (*loc. cit.*) as *A. sydneyensis*, is also probably only a very young Paramatta River form.

(g) *The Blue-Mountain Crayfish* (Pl. XVIII.), found in small streams in the Blue Mountains. The largest specimen obtained by me measured 110 mm. It resembles in every particular Spence-Bate's small Paramatta Crayfish (f). The spines on the carapace, branchiostegites, and abdomen are reduced to small blunt tubercles. This is particularly clear if we compare a specimen of this Crayfish with a similarly sized Victorian specimen, *e. g.*, from the Yarra River. In the latter the dorso-lateral and lateral abdominal spines are far better developed than in the Blue-Mountain or small Paramatta forms. The practical identity of the Blue-Mountain Crayfish with the small Paramatta form described by Spence-Bate seems to me to make it undesirable to invent another name for it.

Note.—Nobili, in his paper in the ‘Annali del Museo Civico di Genova,’ vol. xl. p. 244, 1901, describes a specimen of *Astacopsis* identical with Milne-Edwards’s *A. australiensis*, as coming from Sorong, New Guinea. The occurrence of an *Astacopsis* in New Guinea is so utterly at variance with all the known facts of the distribution of Australian Crayfishes that I am unable to accept the locality of this single specimen as correct, especially as all the subsequent expeditions to New Guinea have failed to find any *Astacopsis* there, although *Cheraps* in abundance have been obtained. Dr. Calman has suggested to me that Sorong was probably wrongly read for Sydney, or else that the label for this specimen had been somehow transposed. Until further evidence is forthcoming as to the occurrence of an *Astacopsis* in New Guinea, the locality given for this single specimen, which is identical with the small Paramatta form of *A. serratus*, must be received with the greatest scepticism.

Remarks on the above species.—For including all the above forms under one species, *A. serratus*, ranging from the Murray River to Sydney, I shall be blamed by many systematists, but the problem is one of peculiar difficulty. The Freshwater Crayfishes, like so many of the large Decapods, begin breeding long before they have attained their limit of size; we are therefore often puzzled to know whether a particular set of specimens represents a separate species, or only not fully-grown individuals of a species which progressively alters as it grows older. It seems undoubted that the large Murray River and the Paramatta River Crayfishes are identical. It is true that the geographical separation of the Murray and Paramatta is not so great as it looks, as the Lachlan River, a tributary of the Murray, rises in the Blue Mountains on the other side of the watershed to that on which the Paramatta rises. The Yarra, Bunyip, and other rivers of the Victorian Highlands are similarly divided from the Murray tributaries, and here, although the differences are very slight, it may be possible to separate a true variety of Crayfish inhabiting these rivers from the Murray River form. The small Blue-Mountain Crayfish bears much the same relation to the big Paramatta form as the small Tasmanian Crayfish to the big one.

Unlike the genera *Cheraps* and *Engæus*, they are not known to leave the water and migrate across the land, so that the various races of this species must have been isolated from one another for very long periods.

ASTACOPSIS KERSHAWI, sp. n. (Pls. XIX., XX.)

The Large Gippsland Crayfish. (Pl. XIX.)

The rostrum is broader than in *A. serratus*, with blunter tuberculated spines on its keels, thus approaching *A. franklinii*.

The spines on the carapace are replaced by blunt, rounded tubercles and ridges. Similarly, the sharp spines present on the

branchiostegites of *A. serratus* are replaced by blunt, often tumid tubercles.

The interantennal spine, the margins of the upper lip, and the antennal scales approach the condition found in *A. franklinii*, and the sternal keel is sharper than in *A. serratus*.

The first abdominal segment has only one lateral spine (in two out of the three specimens this spine was absent on one side). The second abdominal segment has three lateral spines on each side and one dorso-lateral; the dorsal spine present in *A. serratus* is replaced by a very large tumid tubercle which is joined by a ridge to its fellow of the opposite side.

The succeeding three segments have one to three lateral spines on each side and a dorso-lateral, the dorsal spine of *A. serratus* being replaced by a tumid tubercle. The sixth abdominal segment, telson, and uropods are provided with several small spines. The chela is less elongated and more stoutly built than in *A. serratus*, and very often carries spines or tubercles on the dactylopodite and on the surfaces of the carpopodite which are non-tuberculous in *A. serratus*.

The largest specimen was 10 inches long.

Locality.—Moe River, Gippsland. Three specimens collected by Mr. Kershaw.

Local Variety.—*The Small Gippsland Crayfish*. (Pl. XX.)

Several rather small specimens from the Narracan River and a number of other small Gippsland streams (largest specimen 5 inches in length) agree with *A. kershawi* in the broad truncated form of the rostrum, sharpness of sternal keel, and replacement of spines by blunted tubercles, thus differing in diagnostic characters from the smaller specimens of *A. serratus* from the Victorian Highlands. Except in point of size, it is impossible to separate these specimens from the large *A. kershawi*, of which they are probably only the not fully grown individuals.

Remarks on the above species.—There can be no doubt that this Gippsland Crayfish is specifically distinct from *A. serratus*. It is of considerable interest to observe that it approaches in many respects the Tasmanian *Astacopsis* with which it is geographically related, being separated by the comparatively modern Bass's Straits.

Genus PARACHÆRAPS, gen. nov.

Arthrobranch of last leg but one rudimentary, consisting of a stout fleshy peduncle tipped with a few minute filaments which end in long curved hooks (Pl. XXVI, figs. 16, 18). Ala on anterior podobranchs is broad and conspicuous, and carries small filaments. The majority of gill-filaments attached to the stems of all the gills are furnished with long recurved hooks at their ends. The other filaments are frequently pointed at the end.

The hooked setae on coxopodites and on gill-stems are very sharply recurved (fig. 17).

The antennal scale is broad, with the inner margin widening suddenly after the terminal spine (fig. 20).

Mandibles with two prominent teeth and a serrated lower edge (fig. 24).

First maxilla with endopodite consisting of a basal segment and a minute terminal segment (figs. 15, 23).

Second maxilliped with penultimate segment bearing an upper lobe which does not project forwards nearly so far as the tip of the terminal segment (fig. 22).

Third maxilliped without a serial row of bristles, but with the face of the third and fourth segments provided with a double fringe of slender crowded hairs. The exopodite exceeds the third segment of endopodite in length (fig. 21).

Great chela with the carpus long and stout, especially in the male; on the underside a longitudinal ridge is present, often with slight excavations on either side of it. The surface is smooth; there is no row of tubercles on the outer border, but there is a conspicuous fringe of downy hairs on the inner border.

Succeeding legs with terminal and subterminal joints smoother, with very few bristles.

Opening of vas deferens situated on a long projecting and complicated papilla.

The keel of the rostrum is flat and smooth; the lateral carina on carapace also continuous and smooth; there is no median carina.

The distance between the tip of the rostrum and the cervical suture is shorter than between the cervical suture and posterior border of carapace.

The carapace is smooth; the abdominal segments are smooth and non-setose.

The sternal keel is fairly prominent and sharp.

The interantennal spine is rounded, and does not end in a sharp point (fig. 19).

The membranous portion of telson and uropods is long compared to the upper calcified portion, and the median spine on the endopodites of the uropods is in consequence situated mesially.

Remarks on the above genus.—In creating the above genus for the reception of the single species, *P. bicarinatus*, I have been influenced by the following facts. Although *P. bicarinatus* does not differ in any very striking characters from the species which I retain in Erichson's genus *Cheraps*, yet if it were included in this genus it would occupy an altogether isolated position, both as regards structure, geographical distribution, and the fact that from it has probably been derived the large and varied genus *Engarus*. For convenience' sake, therefore, and for the purpose of bringing out its peculiar importance in the evolutionary history of the Australian Crayfishes, I have after much hesitation decided to separate it off from the related forms retained in the genus *Cheraps*. Since *P. bicarinatus* is one of the oldest-known species from Australia, I had originally intended keeping the

name *Cheraps* for it, and placing the Western-Australian species in a new genus, *Paracheraps*. But, as M. Roux, of the Basle Museum, pointed out to me, the term *Cheraps* was first used by Erichson (Arch. f. Naturg. xii. 1846, p. 101) for the species *C. preissii*, which, whatever it may be, does not seem to be identical with *P. bicarinatus*. From Erichson's diagnosis of the genus *Cheraps* and of the single species *C. preissii*, which he includes in it, I find it quite impossible to discover what species of Australian Crayfish he was dealing with. No figures are given, and the only characters mentioned which are of the slightest diagnostic value are the facts that the animal came from Western Australia, that the tail fan was in part membranaceous, and that the antennal scale was "egg-shaped and pointed." No mention whatever is made of any keels on the carapace, a point noticed by Haswell in his 'Catalogue of the Stalk- and Sessile-eyed Crustacea of the Australian Museum,' who gives as a character of *C. preissii* "the absence of keels on carapace(?)."

The balance of evidence seems favourable to the idea that Erichson's really worthless description of *C. preissii* does refer to a species of *Cheraps* and not to *Paracheraps bicarinatus*, so that the term *Cheraps* must be kept for the Western-Australian species.

PARACHERAPS BICARINATUS Gray. (Pls. XXI. & XXVI. figs. 15-24.)

The Yabber.

(Eyre's Journals of Expeditions of Discovery into Central Australia, vol. i. 1845.)

Nomenclature:—

Astacus bicarinatus Gray, *loc. cit.* p. 410, pl. iii. fig. 2.

Cheraps bicarinatus Von Martens, Monatsbericht Akad. Wiss. Berlin, 1868, p. 617.

Astacopsis bicarinatus Haswell, Australian Museum Catalogues, v. Crustacea.

Astacoides bicarinatus McCoy, Prodromus of the Zoology of Victoria, vol. i. pl. 29, 1885.

The rostrum is without pronounced keels; it terminates in a spine, just below which two small lateral spines indicate the beginning of the much-reduced keel.

The lateral carina on the carapace is a continuous blunt ridge. There are no other tubercles or spines on the carapace or body and there are no hairs except at the lateral borders of the carapace and abdominal segments and on the limbs. The surface of the carapace is, however, usually pitted superficially.

The telson is broadly ovate, and there are two small spines laterally at the junction of the hard and membranous portions. There are no median spines.

In the great chela the dactylopodite is not larger than the

carpus; there is a row of about 8–10 tubercles on the inner border of the carpus and just above this row there is a thick carpet of downy hair. An inconspicuous tuberculation and a certain amount of downy hair is present between the pincers. The meropodite has three tubercles and a certain amount of down, and the inner border of the ischiopodite has the usual double row of tubercles.

The succeeding legs are remarkably smooth and free from hairs, though the last two joints of the last two legs are fairly hairy.

The sternal keel is fairly sharp, but not very prominent, and the basal joints of the legs in the neighbourhood of the keel are hairy.

The interantennal spine is rounded and does not end in a sharp point (Pl. XXVI. fig. 19).

The largest specimen is 6 inches in length.

Colour (McCoy).—The whole body and abdomen is dull pale olive, varying in some specimens to greenish horn-colour; membranous part of tail-flaps pale brown; anterior part of legs bright blue; basal and outer portion of hand mottled with scale-shaped spots of dull ochreous yellow; skin of joints bright red.

Locality.—The type specimens are from the pond in the Melbourne University Grounds. Similar forms from various localities in Victoria and also from the mud-flats on Murray River. The species is also widely distributed all over Central, Northern, and Western Australia and in Queensland. It is, so far as is known, absent from Tasmania and New Guinea.

Local Varieties:—

(a) Queensland. One specimen measuring $4\frac{3}{4}$ inches found (Oct. 1891) in a field on a hillside at Cooran. The rostrum is rather blunt and truncated; the dactylopodite is longer than carpus; and there are very well-marked pits on the great chela and on the carapace.

(b) Central Australia. Specimens collected during the Horn Expedition are described by Spencer and Hall ('Report of the Horn Expedition to Central Australia,' Part II. Zoology: Crustacea, p. 244) as being similar to ordinary Victorian species. Slight differences are found in size of chela (a very variable character according to growth and sex), absence of lateral spines on rostrum, and the rostral keel is rather well marked. The authors do not, however, propose making a new species for this form.

Remarks on the above species.—If we take into account the habits of this species, which lives in the banks of ponds, quarry-holes, and other stagnant waters, and is occasionally found walking about in fields, there is no difficulty in understanding its wide distribution all over the continent of Australia. It was found in abundance by the Horn Expedition in Central Australia, where it is said to be eaten regularly by the wandering tribes of blacks, who know it as the Yabber. It is not easy to see how it can survive in these arid and desert regions, liable to the most

prolonged droughts, where all except the deepest water-holes dry up, but presumably its burrowing habits save it. It seems probable, from an examination of the anatomical features of the land-Crayfishes of Victoria and Tasmania belonging to the genus *Engaeus*, that this latter genus has been derived from *Cheraps* by an intensification of the burrowing habit and of the structures associated with it.

Genus *CHERAPS*.

(Erichson, Arch. f. Naturg. xii. 1846, p. 94.)

Arthrobranch of last leg but one somewhat reduced, but without fleshy peduncle and consisting of fairly numerous small filaments springing from a very short base. These filaments are pointed at the end (Pl. XXVII. fig. 25). The ala on the podobranchs is broad as in *Parachærops*. Many of the gill-filaments attached to stem of podobranchs carry long curved hooks as in *Parachærops*; the filaments on the other gills are either round or pointed, but do not carry hooks (fig. 26).

The hook-setæ on coxopodites are sharply recurved.

The antennal scale is not broad as in *Parachærops*, but broadens gradually after terminal spine (fig. 28).

The lateral keels of the rostrum are usually very sharp and conspicuous, but they may be absent (*C. intermedius*).

The lateral carina on carapace is well marked, and may be very sharp and prominent, and there may also be a well-marked median carina.

The distance between the tip of the rostrum and the cervical suture is distinctly longer than that between the cervical suture and the posterior border of carapace.

The sternal keel is sharp and very prominent (fig. 31).

The interantennal spine ends in a sharp point (fig. 27).

The great chela has the carpus either very long and slender, and unprovided with a carpet of downy hairs, or else provided with hairs and stoutly built.

In all other respects the generic characters, *e. g.* of the mouth-parts, telson, and uropods, etc., agree exactly with *Parachærops*.

Remarks on the above genus.—The diagnostic characters by which *Cheraps* may be distinguished from *Parachærops* are (1) the nature of the posterior arthrobranch, (2) the antennal scale, (3) the distance between cervical suture to rostrum and cervical suture to posterior border of carapace, (4) the interantennal spine, and (5) the sternal keel.

CHERAPS QUINQUECARINATUS. (Pls. XXIII. & XXVII. figs. 25–29.)

The Gilgil.

(Gray, Eyre's Central Australia, vol. i. p. 410, pl. iii.)

The rostrum is moderately excavated, with rather prominent

keels; it ends in a sharp spine, with two lateral serrations on each side.

The lateral keel on the carapace is prominent and arched outwards; anteriorly it does not terminate in a prominent spine. There is a well-marked median keel.

There is no prominence on the carapace behind the postorbital spines, nor are there any tubercles upon the carapace, branchiostegites, or abdomen; nor are there any bunches of hairs.

The first maxilla has the terminal segment or flagellum of the endopodite entirely repressed (Pl. XXVII. fig. 29).

The third maxilliped has its inner borders abundantly clothed with hair.

On the telson there are two lateral spines, but no medio-lateral ones.

The great cheliped is long, but not slender; the carpus is very long, but stout; the dactylopodite is only about one-third as long as the carpus. The pincer is slightly tuberculated internally and there is a carpet of fine hairs upon the inner margin of the carpus. There is a row of small tubercles upon the upper ridge of the ischiopodite.

Greatest length $4\frac{1}{2}$ inches.

Locality.—Western Australia, in streams tributary to the Swan River.

CHÆRAPS TENUIMANUS, sp. n. (Pls. XXII. & XXVII. fig. 30.)

The rostrum is deeply excavated in the middle, with sharply upstanding lateral keels. The rostrum ends in a sharp spine, and there are three lateral serrations on each side.

The lateral keel on the carapace is prominent and arched outwards, ending anteriorly in a prominent spine. The median keel is also much pronounced.

There is a distinct prominence on the carapace running back from the postorbital spine, on which a few small tubercles are situated. There are also a few small tubercles on the branchiostegites, and the body is covered with numerous groups of short inconspicuous hairs.

The first maxilla has the endopodite consisting of a broad basal segment, with the flagellum represented by a small conical segment, the base of which is much smaller than the top of the segment with which it articulates (Pl. XXVII. fig. 30).

The third maxilliped is only sparsely provided with hairs.

On the telson, besides the two lateral spines at the junction of the calcified and membranous portions, there are two median spines.

The great cheliped is fairly long and very slender. The carpus is long and slender; the dactylopodite is more than half as long as the hand. There are no enlarged tubercles on the pincer and there is no carpet of fine hairs on the inner margin of the carpus. The row of tubercles on the upper ridge of the ischiopodite is reduced to one or two small tubercles.

The largest specimen measures $6\frac{1}{2}$ inches. Specimens in British Museum about 11 inches.

Locality.—Margaret River, Western Australia.

CHERAPS QUADRICARINATUS. (Pls. XXIV. fig. 1; XXVII. figs. 31–33.)

(Von Martens, Monatsbericht Akad. Wiss. Berlin, 1868, p. 617.)

Nomenclature:—

Cheraps quadricarinatus Von Martens.

Astaconephrops albertisii Nobili, Annali del Museo Civico di Genova, xl. 1899 (1901), p. 244.

The keels of the rostrum are well marked and continued far backwards on to the carapace; the rostrum ends in a sharp spine, and there are three sharp lateral serrations on each side of the rostrum.

The lateral keels on the carapace are well marked and sharp; they are arched outwards and end anteriorly in a sharp spine. There is no median keel.

The carapace and branchiostegites are smooth, except for the presence of three sharp spines laterally on each branchiostegite just posterior to the cervical suture.

The first maxilla has the endopodite consisting of a base and a fairly distinct flagellum jointed on to it.

The third maxillipede has the third and fourth segments sparsely fringed on the inner and outer face with bristles (Pl. XXVII. fig. 32).

The great cheliped is very slender and small, with slender carpus; the carpus is smooth except for a fine serration on inner border, and there is no carpet of downy hairs upon it. A pad of fine hairs is, however, present on the inner face of the meropodite between the spines. The row of tubercles upon the upper ridge of the ischiopodite is represented by a single spine.

The succeeding two chelate legs are provided with a few hairs on the terminal segment. The two posterior non-chelate legs have a fringe of hairs on the last two segments.

The telson is without median spines.

Length about 4 inches.

Locality.—From Cape York, N. Australia (*Von Martens*), and Katau, New Guinea (*Nobili*). Also from Aru Islands (var. *aruanus*) and Mainikion, Baie Etna and Sabang, New Guinea (var. *lorentzi*) (*Roux*).

Remarks.—Through the kindness of Dr. Gestro, of Genoa, I have been able to examine the single New Guinea specimen described by the late Dr. Nobili. In the characters of the gills, coxopoditic setae, mouth-parts, antennal scale, interantennal spine, sternal keel, and general structural features it falls clearly within the diagnosis of our genus *Cheraps*. Dr. Nobili, in regarding it as allied to the New Zealand *Paranephrops*, was apparently led astray by not having ever seen any of the Western Australian

Parachaeraps. My identification of the New Guinea form with Von Martens's *Chæraps quadricarinatus* appears to me certain from his description of the keels, tail-fan, and chelipeds of his Cape York specimens.

Since the above was written, Dr. Jean Roux, of Basle, has described certain specimens belonging to the genus *Chæraps* which are evidently closely allied to *Chæraps quadricarinatus*. He has also re-examined the specimen described by Nobili as *Astaconephrops albertisii*, and comes to the same conclusion as myself that this specimen is an undoubted *Chæraps*, practically identical with *C. quadricarinatus*. Dr. Roux remarks, however, that Nobili's specimen has three serrations on the rostrum, whereas *C. quadricarinatus* only possesses two, and he therefore proposes to keep Nobili's species as valid. Since no other differences are to be observed, it seems to me desirable to examine many more specimens of both varieties before accepting Nobili's species on this single difference.

Dr. Roux also creates two new species, separate from *quadricarinatus*, for his specimens from the Aru Islands and for those from other localities in New Guinea. Here, again, he admits the practical identity of his forms with *quadricarinatus*, but calls attention to certain differences in the proportions of the cheliped, especially in the male. He also finds in the males of his *C. aruanus* and *C. lorentzi* that the internal border of the carpus of the cheliped in the male possesses smooth soft areas, which have not been observed in *C. quadricarinatus* or *albertisii*. It seems possible that these areas may be only developed periodically, as Calman suggests, and that they do not represent specific characters. Without venturing to dogmatise on the subject, it seems premature to accord these varieties of *C. quadricarinatus* more than subspecific rank, especially as the variability of the cheliped in the Crayfish according to age and individuality is notorious. (See Dr. Jean Roux (15, 16), Zoologischer Anzeiger, Bd. xxxvii. Nr. 5, p. 104, Feb. 1911, and Notes from the Leyden Museum, vol. xxxiii. p. 81, 1911.) Calman (17) has examined a number of specimens from the Mimika River, New Guinea, and has observed soft areas on the claws of the male identical with those observed by Roux, and he also notices variations in the proportions of the chela, which, however, graduate into one another. He is emphatically of the same opinion as myself that all these specimens from New Guinea and the adjacent islands hitherto described are not sufficiently distinct to warrant their separation into more than one species.

I am therefore all the more inclined for the present to preserve the name *quadricarinatus* for all these forms.

CHÆRAPS INTERMEDIUS; sp. n. (Pls. XXIV. fig. 2; XXVII. fig. 34.)

The rostrum is flat and quite unexcavated, without any lateral

keels upon it. It ends in a spine and there are two inconspicuous lateral serrations on each side. It closely resembles the rostrum of *Parachærapa bicarinatus*.

The lateral keels on the carapace are blunt and deepened, ending posteriorly in a rounded boss. There are no other tubercles, prominences, or groups of hairs upon the body. So far the external features are practically identical with *P. bicarinatus*, but it can be at once distinguished by the generic character of the length between tip of rostrum and cervical suture being greater than that between cervical suture and end of carapace.

The first maxilla has a very small pointed terminal segment on the endopodite, which articulates by a broad base on to the basal segment (Pl. XXVII. fig. 34).

The third maxilliped is fairly well provided with hairs on its inner borders.

There are no median spines on telson.

The great cheliped is stout and broad; the hand itself being broad and rather flattened; the dactylopodite is about equal in length to the inner border of the carpus. The finger is definitely tuberculated internally, often with two enlarged tubercles. There is a small carpet of fine hairs on the inner margin of the carpus. On the under side the carpus has a pronounced longitudinal ridge with marked excavations on either side of it.

The upper ridge of the ischiopodite has a row of small round tubercles upon it.

Length 4 inches.

Locality.—Two specimens from Western Australia, April 30th, 1880. No further locality given.

Remarks on the above species.—This species is of considerable interest, as it forms a transition from the genus *Chærapa* to *Parachærapa bicarinatus*. In general appearance, in the features of the claws, carapace, rostrum, etc., it agrees exactly with *Parachærapa*; in the fact that the posterior arthrobranch is not rudimentary, the sternal keel is sharp and very prominent, the interantennal spine is pointed and not rounded, the antennal scale is not conspicuously broad, and in the length between tip of rostrum and cervical suture being greater than between latter and end of carapace, it exhibits the characteristic features of the genus *Chærapa*.

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EXPLANATION OF THE PLATES.

PL. XIV.

Astacopsis franklinii, male. Large form. $\frac{1}{2}$ nat. size. North Tasmania.

PL. XV.

Astacopsis franklinii, female. Small *tasmanicus* form. Nat. size. South Tasmania, Mt. Wellington.

PL. XVI.

Astacopsis serratus, male. Large form. $\frac{1}{2}$ nat. size. Murray River.

PL. XVII.

Astacopsis serratus, female. Small form. $\frac{3}{4}$ nat. size. Yarra River.

PL. XVIII.

Astacopsis serratus, male. Small form. Nat. size. Blue Mountains.

PL. XIX.

Astacopsis kershawi, male. Large form. $\frac{1}{2}$ nat. size. Moe River, Gippsland.

PL. XX.

Astacopsis kershawi, male. Small form. Nat. size. Narracan River, Gippsland.

PL. XXI.

Paracharaps bicarinatus, male. $\frac{3}{4}$ nat. size. Melbourne University pond.

PL. XXII.

Charaps tenuimanus, male. $\frac{3}{4}$ nat. size. Margaret River, Western Australia.

PL. XXIII.

Charaps quinquecarinatus, male. $\frac{3}{4}$ nat. size. Swan River, Western Australia.

PL. XXIV.

Fig. 1. *Charaps quadricarinatus*, male. $\frac{3}{4}$ nat. size. From Katau, New Guinea. Thoracic legs not represented. From a specimen lent by Dr. Gestro.

Fig. 2. *Charaps intermedius*, male. Nat. size. Western Australia, locality not known.

PL. XXV.

Fig. 1. Third maxillipede of *A. franklinii*.

Fig. 2. Second maxillipede of ditto.

Fig. 3. First maxillipede of ditto.

Fig. 4. Second maxilla of ditto.

Fig. 5. First maxilla of ditto.

Fig. 6. Mandible of ditto.

PL. XXVI.

Fig. 7. Head of *A. franklinii* from ventral view. To show interantennal spine and upper lip.

Fig. 8. Antennal scale of *A. franklinii*.

Fig. 9. Endopodite of first maxilla of *A. franklinii*.

Fig. 10. Termination of branchial filament of *A. franklinii*.

Fig. 11. Termination of coxopoditic seta of *A. franklinii*.

Fig. 12. Head of *A. serratus* from ventral view. To show interantennal spine and upper lip.

Fig. 13. Antennal scale of *A. serratus*.

Fig. 14. View of sternum of thorax from ventral surface, showing sternal keel and attachment of thoracic legs in *A. serratus*.

Fig. 15. Endopodite of first maxilla of *Paracharaps bicarinatus*.

Fig. 16. Termination of branchial filament of *P. bicarinatus*.

Fig. 17. Termination of coxopoditic seta of *P. bicarinatus*.

Fig. 18. Terminal portion of the last arthrobranch of *P. bicarinatus*.

Fig. 19. Interantennal spine of *P. bicarinatus*.

Fig. 20. Antennal scale of *P. bicarinatus*.

Fig. 21. Third maxillipede of *P. bicarinatus*.

Fig. 22. Second maxillipede of *P. bicarinatus*.

Fig. 23. First maxilla of *P. bicarinatus*.

Fig. 24. Mandible of *P. bicarinatus*.

PL. XXVII.

Fig. 25. Last arthrobranch of *Charaps quinquecarinatus*.

Fig. 26. Termination of branchial filament from pleurobranch of *C. quinquecarinatus*.

Fig. 27. Interantennal spine of *C. quinquecarinatus*.

Fig. 28. Antennal scale of *C. quinquecarinatus*.

Fig. 29. Endopodite of first maxilla of *C. quinquecarinatus*.

Fig. 30. Endopodite of first maxilla of *C. tenuimanus*.

Fig. 31. View of sternum of thorax from ventral surface, showing sternal keel and attachment of thoracic legs in *C. quadricarinatus*.

Fig. 32. Third maxillipede of *C. quadricarinatus*.

Fig. 33. Second maxillipede of *C. quadricarinatus*.

Fig. 34. Endopodite of first maxilla of *C. intermedius*.

11. Structure of the Alimentary Canal of the Stick-Insect, *Bacillus rossii* Fabr.; with a Note on the Parthenogenesis of this Species. By ALFRED E. CAMERON, M.A., B.Sc., Fullerton Scholar of the University of Aberdeen and Research Student in the University of Manchester *.

[Received October 6, 1911: Read November 21, 1911.]

(Plates XXVIII.-XXX.†)

Introductory.

The following description of *Bacillus rossii*, a species of the Phasmidæ, is translated from Girard's 'Traité Élémentaire d'Entomologie' (p. 100) (Paris, 1879).

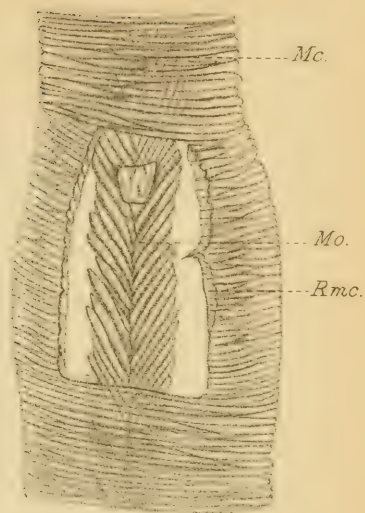
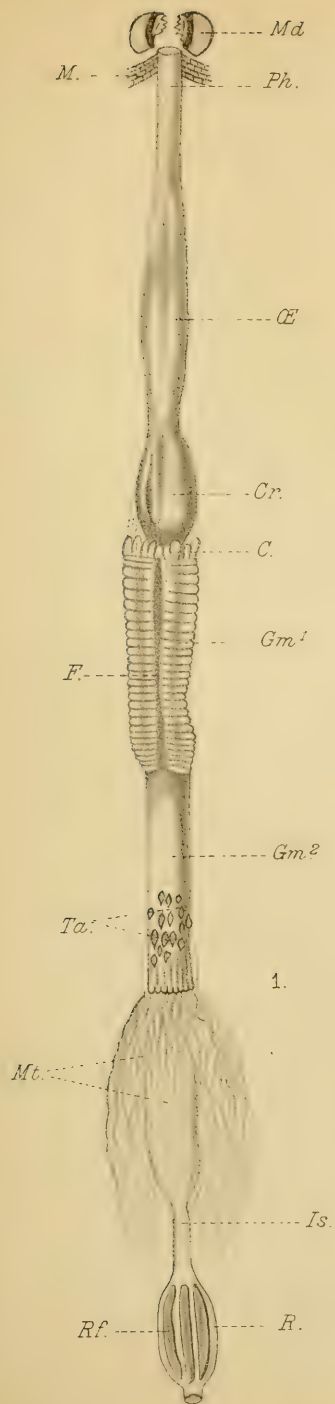
"The genus *Bacillus* is of special interest, as it includes the only species of Phasmid known to occur in Europe; this is *Bacillus rossii* Fabr., green, greyish green, or brownish red, with integument either smooth or bearing slight projections, antennæ composed of 12 to 23 segments, with a dorsal ridge, with slender legs angularly striated, the anterior pair very long, the two posterior pairs of femora tridentate below. The male is from 45 to 55 mm. long, the female from 58 to 108 mm. The species is native to South Europe and North Africa, and was discovered by Rossi in the gardens and heaths of Tuscany; it is common on the green hedgerows bordering water-filled ditches; it is found also in Dalmatia and in Istria. Near the town of Pola this motionless Phasmid occurs on the Montpellier rock-rose; but so great is its resemblance to the twigs among which it lives that it is very difficult of recognition; its enemies, besides parasitic larvæ, are the Praying Mantis and the Green Lizard. A smaller race of *Bacillus rossii* exists with antennæ of 12 segments, thorax bearing minute prominences, the female 54 to 67 mm. in length, of which several authors make a distinct species under the name of *B. gallicus* Charp., *B. granulatus* Brullé, found in Greece at the time of the French expedition, also in Andalusia (Rambur), in North Africa, in the South-East and South-West of France, at Nice, at Cannes, at Hyères, near Toulon. In the early spring the insects may be captured by shaking the bushes over an open umbrella, when there fall into it both adults which have hibernated and larvæ in various stages of development; the larvæ being more delicate than the adults preserve badly when collected, becoming twisted and folded. The species is said to be found in isolated examples as far north as Orleans.

"*B. rossii* is found in Algeria, in places which are covered with grasses and shaded from the light.

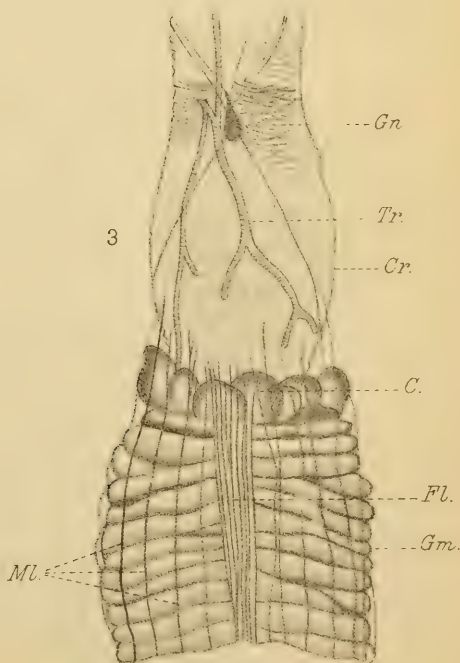
"The genus includes one-fortieth of the species of Phasmidæ of

* Communicated by Professor SYDNEY J. HICKSON, F.R.S., F.Z.S.

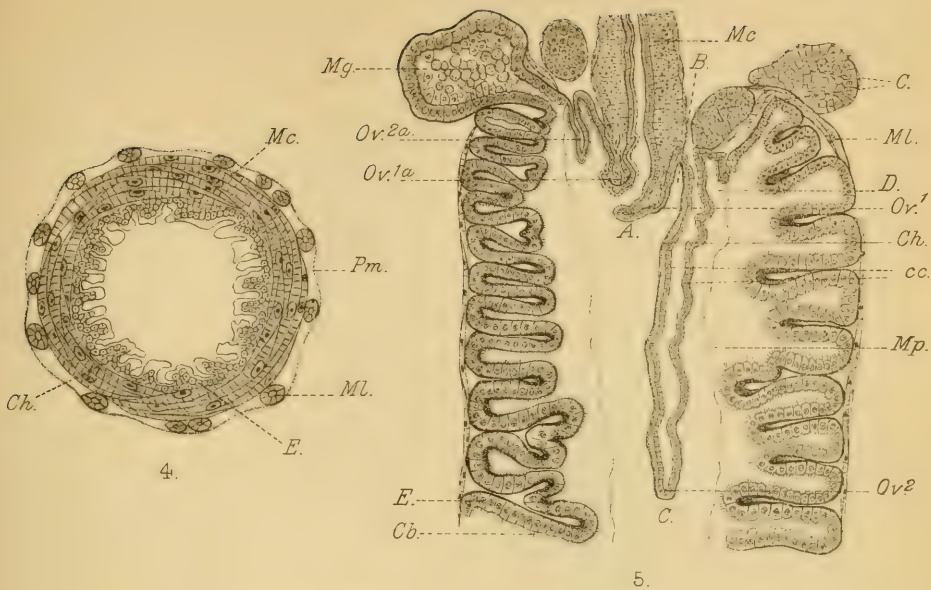
† For explanation of the Plates see p. 182.



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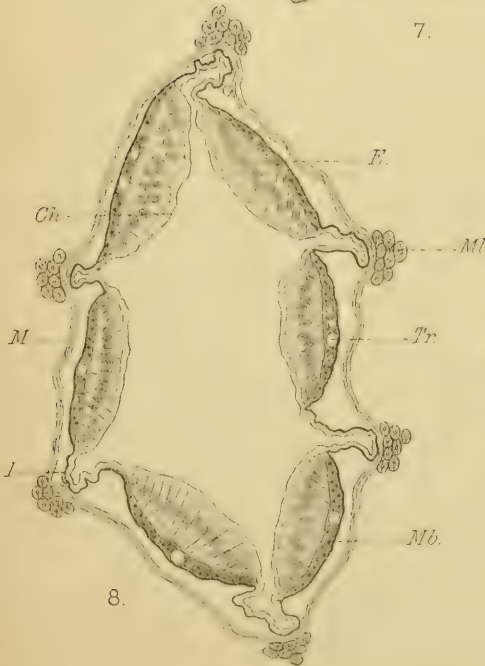


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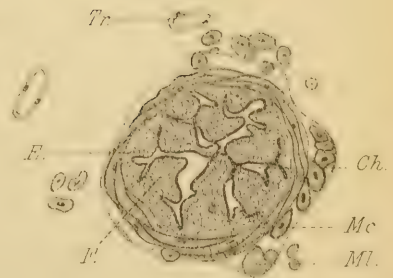




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the Old World, and it has a wide distribution, occurring in Europe, Africa, East Indies, Ceylon, Java, China, Sandwich Islands, Australia, Island of Hamoa, and New Zealand."

In the course of the present year several English collectors have had in their possession specimens which were observed to deposit their ova during the months of February, March, and April, and the hatching of the ova began in the latter part of June. It is highly probable that this insect, alien to the British fauna, made its entrance into this country along with fruit-cargoes and nursery-stock imported from France. There is not much chance of its becoming established here since, being accustomed to mild temperatures, it fares rather badly under the changeable conditions of the English climate. In captivity they require close attention; but by supplying them regularly with fresh food-plants and by keeping the temperature of their surroundings at about average house-temperature they appear to thrive. Under these conditions they are quite healthy, and the mortality is very low.

Note on Parthenogenesis.

A very curious phenomenon in connection with the reproduction of *Bacillus rossii* may be worthy of note. Although my specimens were in the third generation reckoning from the first generation in captivity, no male had been observed, and perhaps parthenogenesis had been the normal method of reproduction previous to this, as my observations were necessarily limited by the fact that I had no record of the generations preceding the first one in captivity. Von Baehr (1907) records that in 1903 he received specimens of *B. rossii* which belonged at least to the seventh parthenogenetic generation, being descendants of a half-grown female captured in Dalmatia in 1896. But the latter, he says, may itself have arisen from an ovum parthenogenetically produced, so that in all probability it was not the first in the ancestral line to produce ova which had not been fertilised by the sperm.

These facts seem to lend support to the supposition that the female of *B. rossii* can dispense with the male altogether and that virgin, rather than sexual reproduction is the normal method adopted by this insect of perpetuating its race. We cannot state with any degree of confidence why the insect has betaken itself to the parthenogenetic production of eggs, but that advantages accrue we are tolerably certain. In cases where, owing to some cause or other, there is a scarcity of males, the method would be a decided acquisition, since the great majority of the more prevalent females would stand a very poor chance of ever meeting a male and of the consequent enjoyment of sexual intercourse.

I think that it is open to make the hypothesis that both sexes of *B. rossii* originally existed in equal numbers. Owing to some cause with which we are not acquainted, the males began to

diminish so that the dominant female, in order to safeguard the species against utter extirpation, began to reproduce parthenogenetically. We must understand that the process has been a very gradual one, proceeding slowly throughout several centuries, the male finally becoming almost extinct.

Another interesting question intimately connected with the subject of parthenogenesis may be asked. Why does the female produce ova from which only females arise? While I offer no suggestion, I may be permitted to allude to the same phenomenon which occurs regularly in many of the Cynipidæ or Gall-flies. The male of *Cynips kollari*, the maker of the marble-gall of the oak, has never been observed, although many entomologists have given this species their close attention, and it is now generally believed that it does not exist, but that parthenogenetic reproduction is the only method of preserving the species.

The following is quoted from Adler and Straton's 'Alternating Generations' (Oxford, 1894).

"It would appear that in *Cynips kollari* the sexual generation is wholly subordinated to the asexual, and in *Rhodites rosæ*, which forms the pretty Bedeguar galls on the rose-tree, the process is still going on, and the males are becoming functionless and extinct. . . . It is difficult to believe that the agamous (or asexual) can be the primitive form; or that the perfectly formed sexual organs could have been evolved unless the sexual had been the earlier generation."

Alimentary Canal.

While at the Royal College of Science, London, in the beginning of 1911, it was suggested to me that the alimentary canal of *Bacillus rossii* would repay careful observation. The material at hand I subsequently worked up in the Zoological Department of Manchester University, and I here take the opportunity of expressing my indebtedness to Professor Hickson as well as to Mr. Mangan for many timely hints.

In the Orthoptera viewed as a whole the alimentary canal shows a very uniform structure; but in the various families there are many secondary differences, sometimes even in the same family, necessitating special description. The gizzard is important in the Orthoptera, and there are diverse degrees of complication in its chitinous armour. The intestinal cæca vary greatly in number, there being eight in Mantidæ and Blattidæ, six in Acridiidæ, and one pair of lateral cæca in Locustidæ and Gryllidæ. The diverse variations of structure in the gizzard, its different degrees of complexity added especially to the presence or absence of intestinal cæca, suggested to Bordas (1897) a method of dividing the Orthoptera into two large groups:

1. The Acolotasia, or Orthoptera without intestinal cæca;
2. The Colotasia, or Orthoptera with intestinal cæca more or less numerous.

The Malpighian tubes in all Orthoptera except the Forficulidæ are very numerous, and are generally grouped in six bundles opening at the summit of six tubercles, as in the Locustidæ and Blattidæ. In all the Gryllidæ, on the contrary, the Malpighian tubes are arranged in a single bundle opening into the dilated extremity of an unpaired excretory canal. Very characteristic is the presence of a "ciliated border" (un revêtement cilié) projecting from the cells of the mid-intestine and lateral appendages.

The alimentary canal of *B. rossii* is divided into three parts, as in all arthropods.

1. Fore-gut, ectodermic, corresponding to the stomodæum, and comprising the mouth, pharynx, œsophagus, and crop (Pl. XXVIII. fig. 1); the gizzard is absent.

2. Mid-gut, endodermic, corresponding to the mesenteron, beginning posterior to the crop and ending at the insertion of the Malpighian tubes. The lateral cæca, generally developed from the anterior part of the mid-gut, are rudimentary in *B. rossii* (fig. 1).

3. Hind-gut, ectodermic, corresponding to the proctodæum, beginning at the insertion of the Malpighian tubes and including small intestine and rectum (fig. 1).

In many respects the alimentary canal is peculiar, and the main features which contribute to its uniqueness may be tabulated as follows:—

1. The rectilinear shape of the gut, there being no convolutions of the posterior region (fig. 1).
2. The complete absence of the gizzard.
3. The rudimentary nature of the mid-gut digestive cæca (figs. 1 & 3, C.).
4. The presence of numerous peculiar conical tubular organs on the posterior position of the mid-gut (fig. 1, Ta.).

In preparing sections for histological examination of the gut various stains were employed. Grenacher's hæmatoxylin was especially good in the differentiation of chitin, while Heidenhain's iron-hæmatoxylin proved very effective where epithelium was concerned. Professor Hickson's brazilin stain and borax carmine were also used to advantage. To get the best results the gut required rather careful treatment, and in the matter of a fixing agent I found that Schaudinn's fluid was all that could be desired.

It is generally accepted that the mid-gut of insects is endodermic in its origin, but in the case of *B. rossii* Heymons (1897) demonstrated that it was really ectodermic, being developed from two epithelial outgrowths of the stomodæum and proctodæum which surround the yolk and become united. This manner of formation, he maintains, may be found to hold good for all Phasmidæ.

The fore-gut up to and including the crop is of rather simple structure. As a rule the histological structure of the insect alimentary canal is always the same: on a layer composed of muscular and connective tissue there rests an epithelium which secretes a strong chitinous lining. This cuticle is raised into straight longitudinal ridges which bear numerous minute horny denticulations. The pharynx of *B. rossii* (fig. 1, Ph.) is very short and is lodged in the posterior cephalic region, the oesophagus (fig. 1, Œ.) occupying the elongated prothorax and passing insensibly into the somewhat dilated crop (fig. 1, Cr.) in the region of the mesothorax. Lastly, the crop joins the mid-gut (fig. 1, Gm₁) in the region of the metathorax, and, indeed, the internal wall of the crop is telescoped into the cavity of the mid-gut as a cone-shaped prolongation (Rüssel). But in addition to what may be called the primary direct extension of the crop (Pl. XXIX. fig. 5, Ov₁ and Ov_{1a}) there is also a secondary indirect extension (fig. 5, Ov₂ and Ov_{2a}). The chitinous epithelial cells of the wall of the crop extend backward into the mid-gut for a short distance as far as the point A denoted in the figure. They then become folded back on themselves up to the point B, and turning once more form the long dorsal prolongation which reaches a comparatively long way into the mid-gut. At C the cells are again reflected, and finally at D join with the larger epithelial cells of the mid-gut. The chitinous cuticle lining the prolongations is continuous with that of the crop. From fig. 5 it will be observed that the extensions are not symmetrical but are much more pronounced dorsally than ventrally. This unsymmetrical arrangement is known to occur only in the few Phasmids in which the alimentary canal has been investigated, and the exact reason of the greater development of the dorsal lamina is not known. In the larvæ of *Chironomus* the oesophageal telescoping is uniform and symmetrical, and I believe that this is the case with the majority of insects where the telescoping occurs.

Heymons (1897) gives it as his opinion that the elongate dorsal lamina (Verschlussklappe) functions as a closing-valve, preventing the back-flow of digested food from the mid- to the fore-gut. But Sinéty (1901) does not agree with this interpretation, as he is convinced that if the direction of the food-current were to be reversed this flap would be overcome by the pressure. The bundles of circular muscle surrounding the anterior part of the mid-gut would be quite effective in checking the reversed food-current if any such occurred.

The mid-gut of *B. rossii* is divided into two distinct parts, of which the anterior is characterised by very prominent transverse folds (Pl. XXVIII. fig. 1, Gm₁; fig. 3, Gm₁; Pl. XXIX. fig. 5); while the posterior (fig. 1, Gm₂), besides being narrower, is easily distinguished by the presence on its external walls of numerous (about 50) conical, tubular organs (fig. 1, Ta₁).

In all Orthoptera as before stated, except the Phasmidæ, the surface of the mid-intestine is enlarged by diverticula of various

shapes developed from the anterior end, eight long cylindrical cæca in Blattidæ and Mantidæ, two large rounded cæca in Locustidæ and Gryllidæ, or again six pouches in Acridiidæ, which may be further provided with inferior appendages. In *B. rossii* these cæca (fig. 1, fig. 3, fig. 5, C.) exist merely as small lobes clustered together in small numbers and very rudimentary. These cæca must not be confused with the gland-like structures (fig. 1, Ta.) which occur just anterior to the Malpighian tubes. Indeed it is not definitely known whether the function of these latter so-called "glands" is really glandular, secreting a digestive juice which is poured into the intestine, or excretory, eliminating waste products like the Malpighian tubes. At their point of attachment to the gut these organs are pear-shaped, tapering abruptly into a small tubular thread, the calibre of which is about half the size of that of the Malpighian tubes amongst which they pass. Heymons (1897) has shown that in origin and morphology these tubular appendages bear a very close resemblance to the Malpighian tubes; but physiologically he regards the two sets of organs as different, since they are dissimilar in their behaviour towards injections of coloured particles. Generally speaking, it was found that the tubular appendages were the less sensitive, but they may eliminate some substances quite as actively as the Malpighian tubes, as, for instance, Ehrlich blue. If their function be excretory, it is less general than that of the ordinary organs of excretion.

The internal wall of the mid-gut is composed of a layer of large cylindrical epithelial cells (Pl. XXIX. fig. 5, E; fig. 6, E and E₁) provided with a "striated border" (fig. 5 and fig. 6, Cb.), and further they are characterised by a continual secretion of globules of mucilage (fig. 5 and fig. 6, Mg.), which are deposited in the intestinal cavity. Cuénot (1895), amongst other authors, describes the presence of young cells in this epithelium undergoing mitotic division and gradually replacing the older cells. These are of the nature of small interstitial cells with rather dense, deep-staining nuclei; but I myself have not observed any mitotic figures in them. There is still dispute on the question of these so-called "germinative-centres," and many authors, notably Frenzel (1886) and Visart (1894), consider them as glandular crypts.

There is no protective chitinous cuticle lining the internal walls of the mid-gut, but its place seems to be taken by a very slender peritrophic membrane (figs. 5 and 6, Mp.) which is quite detached from the epithelium. It takes its origin at the point where the fore-gut epithelium joins that of the mid-gut, and extends as far as the hind-gut, which it enters for a short distance. Thus the food passes through the alimentary canal without the delicate epithelial cells running any risk of abrasion from jagged particles eaten by the insect in the course of its diet. This membrane (Trichter) is certainly not a prolongation of the chitinous cuticle of the crop, as Mecznirow and Schneider (1890)

believed, but seems to be secreted by the most anterior epithelial cells of the mid-gut. The question may be asked: How does *B. rossii* assimilate its food? This can only be explained by a knowledge of the laws of osmosis, so that the digestive juices secreted by the epithelium and the fluid juices which result from their action must pass through the membrane, the former to act on the food substances, the latter to be absorbed.

Schneider (1890) and Adlerz have observed the presence of a peritrophic membrane in diverse Orthoptera, *Phyllodromia*, *Periplaneta*, *Bacillus*, *Locusta*, *Forficula*. This has been verified by Cuénot (1895), who adds some details as regards its origin of which little is known.

Plateau (1875), in his splendid work 'Recherches sur les phénomènes de la digestion chez les insectes,' has shown that digestion first begins in the crop, where the alkaline or neutral secretion of the salivary glands acts on starchy substances, changing them to glucose. The processes of digestion are continued in the mid-gut, the epithelium of which also secretes a fluid with alkaline or slightly acid properties which has the power of changing albuminoids into peptones and of emulsifying fats.

Petrunkewitsch (1899) held that in certain Orthoptera the crop was the principal organ for the absorption of digested food, citing as his proof the presence of fat in the epithelial cells. But Sinéty (1901) demonstrated clearly that the fat globules here present are really elaborated by the epithelial cells from materials extracted from the blood, and thus the epithelium of the crop is functionally comparable to the fat-body. Again, many authors adopted the idea that owing to the shortness of the mid-gut supplementary absorption must be carried out in the crop (Plateau [1876] and Jousset de Bellesme in the Blattidæ), or even in the hind-gut (Plateau [1878] and Frenzel [1886]). But from all known laws of osmosis it is highly improbable that this can be the case, for the thick chitinous cuticle lining both crop and hind-gut is impermeable to dissolved substances. Again, it is nothing short of absurd to suggest that absorption can go on below the point of insertion of the Malpighian tubes which mark the posterior limit of the mid-gut, and invariably pour their waste-products into the alimentary canal at this place.

In *B. rossii* the Malpighian tubes (Pl. XXVIII. fig. 1 and Pl. XXX. fig. 7, Mt.) are very numerous and are disposed regularly in a circle round the anterior end of the hind-gut, into which they open in groups of three to six. These groups, occurring to the number of 20 to 30, are equidistant from each other, and the tubes composing any one group fuse at the apex of a small conical tubercle which arises as an evagination from the gut and is traversed by a minute duct (fig. 7, Cd₁ and Cd₂). The constituent cells of the Malpighian tubes also possess the "ciliated border" characteristic of the epithelial cells of the mid-gut, but the "cilia" in both cases do not possess any power of motion even in an indifferent medium. It cannot be argued that the fact of the insect being dissected would cause the "cilia" to cease vibrating immediately, as the cilia on the gill-plates of

Unio, the fresh-water mussel, continue their vigorous movement long after the removal of the gills from the animal. In conclusion I may state that the different authors who have investigated the matter refer to the "ciliated border" under various names, such as "striated plate" "ciliated plate," "plate composed of free-filaments or rods," "brush-like border" (Härchensaum of Frenzel); but all these terms convey to our minds exactly the same idea.

The hind-gut, including the small intestine (Pl. XXVIII. fig. 1, Is.) and rectum (fig. 1, R.), is, like the fore-gut, lined with chitin. In the small intestine I distinguish two regions—the anterior one broad, with small internal longitudinal folds, and the posterior narrow, the circumference of which is greatly lessened by the deep infolding of the epithelium, the lumen appearing only as six narrow bays. Just anterior to the narrowing a circular band of muscle surrounds the small intestine and by its contraction shuts off the anterior from the posterior region. A curious valvular apparatus (Pl. XXX. fig. 9, F.) occurs at the anterior orifice of the rectum in the shape of six muscular pyramidal projections inserted by one of their surfaces in the internal wall of the gut, and with the surface adjacent to the rectum slightly hollowed out. The small intestine can be completely cut off from the rectum by a muscular band on the external wall, which when it contracts brings the six valves together so that the passage is completely closed.

The rectum (fig. 1, R.) bears internally six longitudinal thickenings of large epithelial cells (Pl. XXX. fig. 8, E.) which have a glandular function, and between the epithelial cells and the basement membrane (fig. 8, Mb.) there ramifies a system of tracheæ, suggesting a rather perfect aeration of rectal tissues.

Musculature of the Alimentary Canal.

As always in insects, the gut is provided with two sets of muscles, longitudinal and circular, which extend along its whole length. But in *B. rossii* there is a marked deficiency of longitudinal muscles in the region of the fore-gut, and their place seems to have been in great measure taken by six broad bands of short oblique fibres which belong morphologically to the circular system (Pl. XXVIII. fig. 2, Mo.). On the mid-gut the bands of circular muscles are set wide apart, producing the characteristic furrowed appearance of this region of the intestine.

The longitudinal muscles present some interesting peculiarities. They extend all along the intestine with the exception of the anterior part, as slender fibres equidistant from each other, and numerous branches are given off from the main strands. These branches may anastomose where they run close together, or they may taper off into extremely fine threads. The longitudinal muscles seem to play an important part in connection with the morphological significance of the pyriform organs of the posterior region of the mid-gut. The latter are observed to arise either in close proximity to one, or equidistant from two longitudinal

muscles. In the first case a single branch is given off from the main fibre and may be traced to the surface of the pear-shaped dilatation; in the second case two branch fibres may be supplied, one from each of the two nearest longitudinal muscles. Under a nerve stimulus these branches are said to be the mechanism whereby the mid-gut appendages are animated with a movement analogous to that observed in the case of the Malpighian tubes (Sinéty [1901]).

In the anterior region of the mid-gut there is a distinct dorso-longitudinal furrow (Pl. XXVIII. fig. 1, F, and fig. 3, F₂) in which numerous longitudinal muscles are congregated, and to a less extent the same phenomenon is observable in the ventro-longitudinal furrow. The fibres which are situated dorsally and laterally on the mid-gut are united into three, then into a single strand which proceeds anteriorly to its attachment in the pronotum. Those fibres lying ventrally are united into a somewhat more slender strand.

As they pass backward to the hind-gut the longitudinal muscles become grouped into six strong bands applied symmetrically to the wall of the gut, and giving off distally cutaneous branches which proceed outwards.

Summary.

The alimentary canal of *B. rossii* presents us with much that is of interest. Its rectilinear shape is what we would naturally expect from the narrow elongated form of the insect. But the absence of a gizzard, together with the rudimentary digestive cæca and the presence of tubular filiform organs at once arrest attention. The anterior portion of the mid-gut is puckered owing to the isolation of the circular muscle-bundles. The Malpighian tubes are curiously grouped in bundles of from three to six, each bundle opening into the gut by a common duct. The small intestine is separated from the rectum by six powerful pyramidal valves. The internal wall of the crop telescopes into the lumen of the mid-gut, and the telescoped portion is reflected on itself in a curious manner.

The fact that the males of *B. rossii* are disappearing points to parthenogenesis not being the primitive method of reproduction, but suggests that the species has become adapted to it through the failure of sexual reproduction.

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EXPLANATION OF THE PLATES.

PLATE XXVIII.

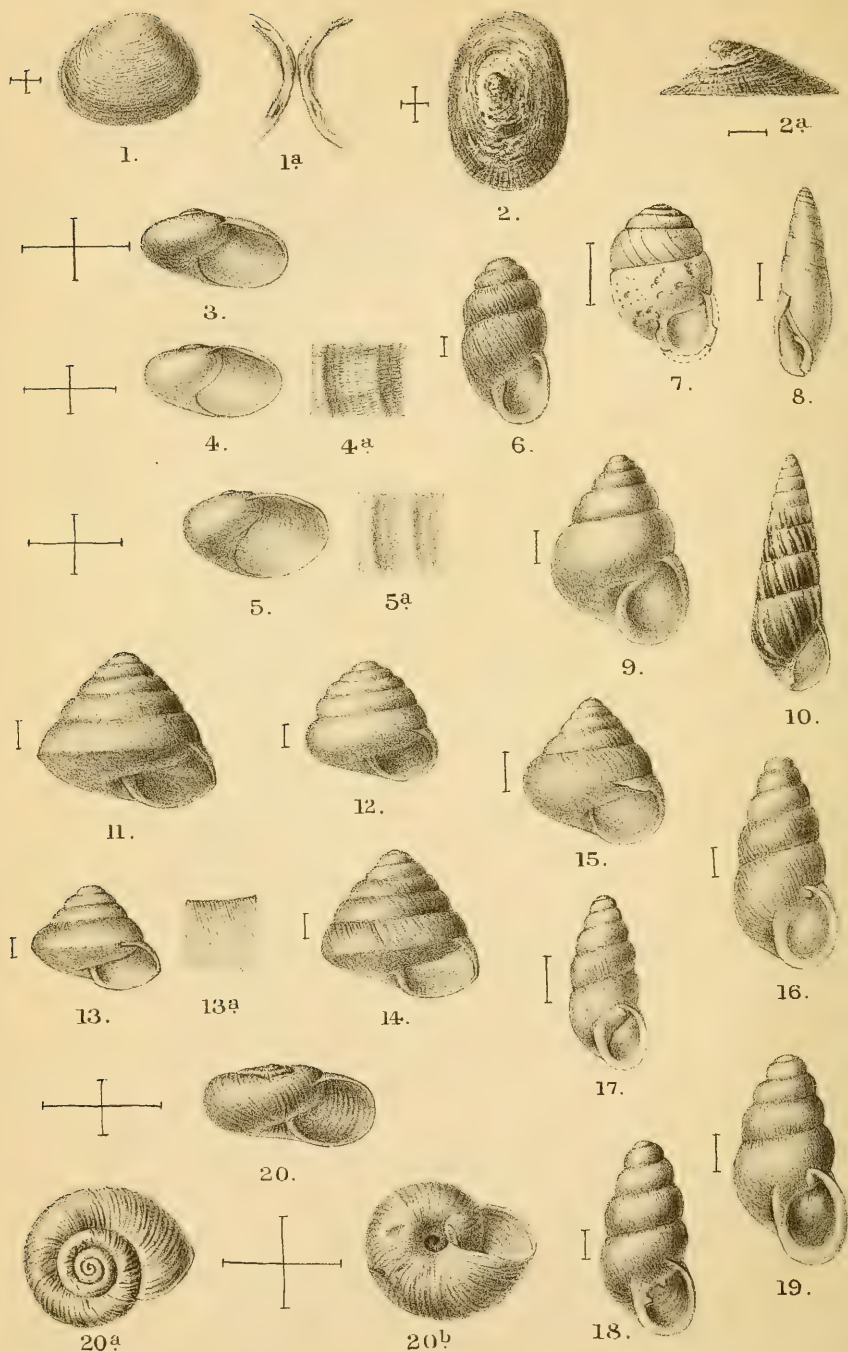
- Fig. 1. Alimentary canal of *Bacillus rossii*. Md., mandibles; Ph., pharynx; M., muscles of the pharynx; Œ., œsophagus; Cr., crop; Gm₁, anterior region of the mid-gut; Gm₂, posterior region of the mid-gut; F., dorso-longitudinal furrow in which several longitudinal muscles are congregated; C., rudimentary cæca of the mid-gut; Ta., tubular appendages of the mid-gut with their filiform prolongations; Mt., Malpighian tubes; Is., small intestines; R., rectum, with the rectal longitudinal folds Rf.
- Fig. 2. Portion of the external wall of the crop. Mc., circular muscle; Mo., band of oblique muscle fibres, of which there are six, extending longitudinally along the œsophagus and crop, and displacing in great measure the ordinary longitudinal muscles; Rmc., circular muscles reflected to show one of the bands of oblique fibres.
- Fig. 3. Crop and anterior part of the mid-gut. Cr., crop; Gn., ganglion; Tr., trachea; Gm., mid-gut; C., rudimentary cæca of the mid-gut; Fl., longitudinal muscles grouped together in the dorso-longitudinal furrow; Ml., longitudinal muscles lying outside the furrow.

PLATE XXIX.

- Fig. 4. Transverse section of the crop. Mc., circular muscles; Ml., longitudinal muscles; Pm., peritoneal membrane; E., epithelial cells which secrete the chitinous lining Ch.
- Fig. 5. Longitudinal section of the posterior region of the crop and anterior region of the mid-gut. Mc., circular muscles of the crop; C., rudimentary digestive cæca; Mg., mucilaginous globules secreted by the epithelial cells of the cæca as also by those of the mid-gut. In the mid-gut these globules occupy the space between the epithelial layer and the peritrophic membrane. They are not included in the figure. Ml., longitudinal muscles; Ch., chitinous lining of the crop secreted by the chitinous cells cc., extending with the "valvular" prolongation into the mid-gut; Mp., peritrophic membrane; E., epithelium of the mid-gut with Cb., the ciliated border; Ov₁, primary dorsal œsophageal "valve" with the corresponding ventral small "valve" Ov_{1a}.
- Fig. 6. Transverse section of the anterior region of the mid-gut. E., epithelium; Cb., ciliated border; E₁, epithelium of an adjacent fold which has also been cut through; Ml₁ and Ml₂, the longitudinal muscles of the dorsal and ventral longitudinal grooves of the mid-gut; Mc., circular muscles; Mp., peritrophic membrane; Pm., peritoneal membrane; Mg., globules of mucilaginous secretion.

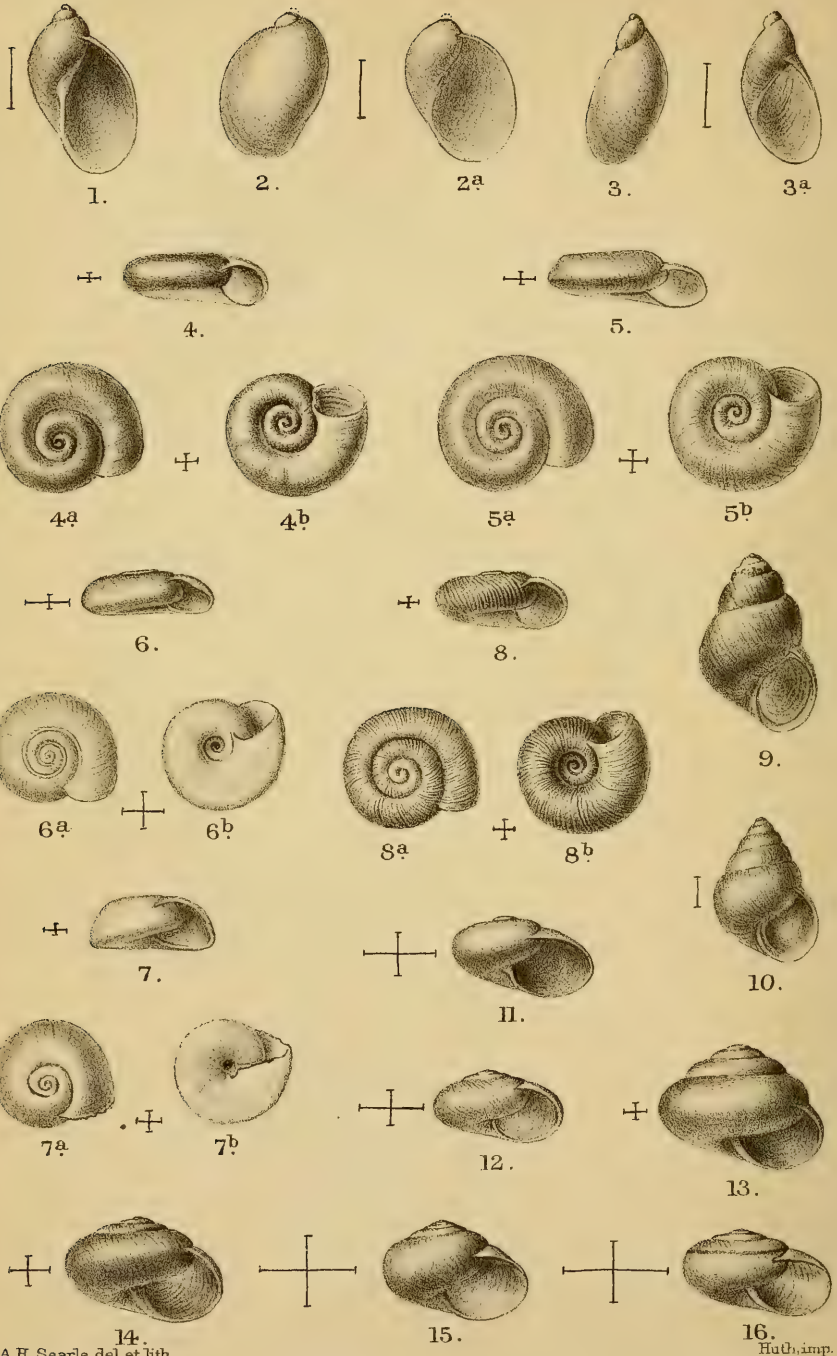
PLATE XXX.

- Fig. 7. Transverse section through the junction of mid- and hind-guts. E., epithelium; Ml., longitudinal muscles; Pm., peritoneal membrane; Mp., peritrophic membrane; Ch., chitinous lining of the hind-gut; Mt., Malpighian tubes; Cd₁ and Cd₂, common ducts of several Malpighian tubes.
- Fig. 8. Transverse section of the rectum. E., band of large epithelial cells, of which there are six; between each two bands there is a non-epithelial interspace I, where the chitinous intima Ch. becomes corrugated and is closely applied to the basement-membrane Mb.; Tr., trachea; M., muscular layer.
- Fig. 9. Section through small intestine at the orifice of the rectum. F., one of the six projections or valves which shut off the small intestine from the rectum; E., epithelium secreting the chitinous intima Ch.; Mc., circular muscle; Ml., longitudinal muscle; Tr., trachea.



A.H. Searle del et lith.

Huth, imp.



A.H. Searle del. et lith.

Hu. G. imp.

NEW AFRICAN TERRESTRIAL AND FLUVIATILE SHELLS.

12. Diagnoses of new Species of Terrestrial and Fluvialile Shells from British and German East Africa, with the Description of a new Genus (*Eussoia*) from the Eusso Nyiro River, B.E. Africa. By H. B. PRESTON, F.Z.S.

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(Plates XXXI. & XXXII.*)

The species described in the present paper were all, with one exception, collected by Mr. Robin Kemp during his more recent travels in British East Africa. As they represent only a very small portion of the large number of species sent home by Mr. Kemp, it will be readily seen what a vast field there is for investigation in the molluscan fauna of this almost hitherto unknown conchological province.

ENNEA MICROSTRIATA, sp. n. (Pl. XXXI. fig. 7.)

Shell scarcely rimate, ovate, edentulate, moderately thin, cream-coloured; whorls 6, the first four small, regularly increasing, the fifth large in proportion, gibbous, the sixth proportionately longer though not quite so broad, marked especially on the fifth whorl with oblique, distant, regular growth-lines, and sculptured with closely-set, microscopic, scratch-like striae; suture impressed, closely and rather finely crenellate below; umbilical area represented by a somewhat broad depression, sloping to an extremely narrow, elongate, and shallow fissure; columella rather vertically descending in a gentle curve; labrum narrowly outwardly expanded, very slightly reflexed; aperture subquadrate.

Alt. 7·5, diam. maj. 5 mm.

Aperture: alt. 2, diam. 2 mm.

Hab. Dar-es-Salaam, German East Africa (*Connolly*).

NATALINA PERMEMBRANACEA, sp. n. (Pl. XXXI. figs. 20, 20 a, 20 b.)

Shell perforate, suborbicular, with almost planulate spire, membranaceous, pale brownish horn-colour; whorls 5, marked with closely-set, oblique, arcuate, transverse wrinkles; suture impressed, very narrowly margined below; umbilicus moderately narrow, deep; columella outwardly expanded above, vitreous, descending in an oblique curve, diffused above into a thin, glassy, ill-defined callus which reaches the upper margin of the labrum; labrum membranaceous, slightly reflexed, receding below, projecting above; aperture ovate.

Alt. 6·25, diam. maj. 14·25, diam. min. 11·75 mm.

Aperture: alt. 6·25, diam. 7·25 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

* For explanation of the Plates see p. 193.

AFRICARION KEMPI, sp. n. (Pl. XXXI. fig. 3.)

Shell subovate, with moderately depressed spire, yellowish brown; whorls 3, marked with arcuate, wrinkle-like growth-ridges; suture impressed, narrowly margined below; columella vertically descending above, somewhat obliquely curved below; labrum simple, projecting in front, receding above and below aperture rather squarely ovate,

Alt. 7, diam. maj. 14, diam. min. 10.75 mm.

Aperture: alt. nearly 7, diam. 8 mm.

Hab. Between Entebbe and Mbarara, S.W. Uganda (*Robin Kemp*).

AFRICARION MICROSTRIATA, sp. n. (Pl. XXXI. figs. 4, 4a.)

Shell rather small, thin, moderately globose, with small and depressed spire, pale yellowish horn-colour; whorls 3, the first two very small, the last proportionately very large, marked with transverse, arcuate growth-wrinkles and microscopic, closely-set, wavy, spiral striae; suture impressed; base of shell rather inflated; columella descending in a strong curve; labrum acute, receding below and sharply above, very prominently projecting in front; aperture very broadly and somewhat compressedly sublunate.

Alt. 5.75, diam. maj. 11.25, diam. min. 8.5 mm.

Aperture: alt. 5.75, diam. 6.25 mm.

Hab. Between Mbarara and Kigezi, extreme S.W. Uganda (*Robin Kemp*).

AFRICARION MICROGRANULATA, sp. n. (Pl. XXXI. figs. 5, 5a.)

Shell differing from *A. microstriata* in its much finer sculpture, the spiral striae being very much finer and still more closely set; moreover, they are crossed by fine, oblique, transverse striae, thus presenting under the microscope a finely granular appearance. The present species is also rather larger, the last whorl is somewhat more inflated, and the labrum less prominently projecting in front; the aperture is much higher in proportion to its breadth, and the columella is even more curved than is the case with *A. microstriata*.

Alt. 8, diam. maj. 12, diam. min. 9 mm.

Aperture: alt. 8, diam. 7 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

VITRINA COMPACTA, sp. n. (Pl. XXXII. fig. 11.)

Shell semiorbicular, not very thin, pale brown; whorls $2\frac{3}{4}$, rapidly increasing, smooth but for radiate lines of growth, the last whorl subangulate at the periphery; suture impressed, slightly crenellate and narrowly margined below; base of shell rather inflated; columella descending in a very gentle curve, narrowly outwardly reflexed and diffused into a light callus which reaches the upper margin of the labrum; labrum simple, the margins converging; aperture broadly subovate.

Alt. 4.5, diam. maj. 9, diam. min. 7 mm.

Aperture: alt. 4, diam. 4.75 mm.

Hab. Between Mbarara and Kigezi, extreme S.W. Uganda
(*Robin Kemp*).

ZINGIS KEMPI, sp. n. (Pl. XXXII. fig. 14.)

Shell small, perforate, thin, rather depressedly turbinate, greenish olive; whorls $3\frac{1}{2}$, the earlier whorls somewhat pitted, the later sculptured with oblique, radiate growth-plates, the last whorl subangulate at the periphery; suture impressed; base of shell slightly inflated; umbilicus narrow, deep, slightly overhung by the outward expansion of the columella; columella somewhat broadly outwardly expanded, descending in a very slight curve; labrum acute, simple, receding below; aperture obliquely subulate.

Alt. 2.5, diam. maj. 5.25, diam. min. 4.5 mm.

Aperture: alt. 2.25, diam. 2 mm.

Hab. Between Mbarara and Kigezi, extreme S.W. Uganda
(*Robin Kemp*).

ZINGIS PAPYRACEA, sp. n. (Pl. XXXII. fig. 15.)

Shell rimate, very thin, globosely turbinate, pale yellowish horn-colour; whorls 5, the first four regularly increasing, the last large, inflated, marked with transverse growth-lines, and minute, wavy, transverse striae; suture impressed, very narrowly margined below: perforation very narrow, almost covered by the outward expansion of the columella; columella outwardly reflexed and vertically descending above, curved below; labrum thin, very slightly reflexed, especially towards the base; aperture very broadly and compressedly subulate.

Alt. 8.25, diam. maj. 13.5, diam. min. 11.25 mm.

Aperture: alt. 6.75, diam. 6.25 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft.
(*Robin Kemp*).

ZINGIS PLANISPIRA, sp. n. (Pl. XXXII. fig. 16.)

Shell perforate, thin, almost membranaceous, very depressedly turbinate, semiorbicular, pale yellowish brown, painted with a super-sutural line of dull reddish purple, which appears on the last whorl as a narrow, super-peripheral band; whorls $4\frac{1}{2}$, somewhat rapidly increasing, the last large and slightly descending in front, sculptured throughout with radiate wrinkles; suture impressed; umbilicus moderately wide, deep; columella descending in a sharp curve, outwardly rather broadly expanded; labrum acute, reflexed throughout; aperture very broadly and depressedly subulate.

Alt. 6.75, diam. maj. 13.75, diam. min. 11 mm.

Aperture: alt. 5, diam. 6 mm.

Hab. Between Entebbe and Mbarara, Uganda (*Robin Kemp*).

In shape resembling the Eastern Helicoid genus *Planispira*.

THAPSIELLA MILLESTRIATA, sp. n. (Pl. XXXII. fig. 12.)

Shell perforate, very depressedly turbinate, thin, pale yellowish brown; whorls $4\frac{1}{2}$, regularly and rather rapidly increasing, marked throughout with radiate and very minute and closely-set, wavy, spiral striæ; suture impressed, margined below; umbilicus narrow, deep, partly concealed by the outward expansion of the columella; columella outwardly expanded above, very obliquely descending, a well-defined, outwardly projecting callus reaching from it to the upper margin of the labrum; labrum thin, acute, receding below; aperture very broadly and compressedly sublunate.

Alt. 4, diam. maj. 8, diam. min. 6.75 mm.

Aperture: alt. 3.5, diam. nearly 4.25 mm.

Hab. Near Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

THAPSIELLA OPPOSITA, sp. n. (Pl. XXXII. fig. 13.)

Shell differing from *Helix zanguabarica* Craven* in being spirally sculptured throughout and in having no transverse striæ on the spire, whereas *H. zanguabarica* has no spirals on the spire but is strongly transversely striate, the basal striæ are not so apparent as those on *H. zanguabarica*; in other respects there is a great resemblance between the two species.

Alt. 1.75, diam. maj. 1.5 mm.

Hab. Mt. Kenangop, Aberdare Range, British East Africa (*Robin Kemp*).

It may be as well to mention here that through the courtesy of Mr. E. A. Smith I have microscopically examined the type specimen of Mr. Craven's species in the British Museum, which is, as stated above, basally spirally striate, though no mention is made of this important character in his description.

KALIELLA CONSOBRINA, sp. n. (Pl. XXXI. fig. 11.)

Shell rimate, conical, pale brownish horn-colour; whorls $5\frac{1}{2}$, sculptured with fine, oblique, slightly wavy, closely-set, transverse striæ, the last strongly carinate at the periphery; base of shell rather inflated, marked with lines of growth and fine, wavy, spiral striæ; suture impressed, narrowly but strongly callously margined above; umbilicus reduced to a mere chink; columella outwardly expanded and very vertically descending above, oblique below; labrum simple; aperture angularly sublunate.

Alt. 3.75, diam. maj. nearly 4, diam. min. 3.5 mm.

Aperture: alt. 1.25, diam. 1.25 mm.

Hab. Between the Igembi Hills and Nyeri, British East Africa (*Robin Kemp*).

KALIELLA DEPAUPERATA, sp. n. (Pl. XXXI. figs. 13; 13 a.)

Shell differing from *K. consobrina* in its smaller size, it having one whorl less, and in its proportionately broader shape, in being very bluntly carinate at the periphery, and in its rather lighter colour; moreover, it lacks the spiral basal striæ of that species.

* Proc. Zool. Soc. London, 1880, p. 217, pl. xxii. figs. 4 a, b, c.

Alt. 2, diam. maj. 2.75, diam. min. 2.5 mm.

Hab. Between the Igembi Hills and Nyeri, British East Africa
(*Robin Kemp*).

KALIELLA KIGEZIENSIS, sp. n. (Pl. XXXI. fig. 14.)

Shell allied to *K. consobrina*, but imperforate, narrower in form, with proportionately higher aperture and rather finer transverse sculpture; the columella also descends vertically throughout its whole length.

Alt. 3, diam. maj. 3.25, diam. min. 3 mm.

Aperture: alt. 1.25, diam. 1 mm.

Hab. Between Mbarara and Kigezi, extreme S.W. Uganda; also at various points in the neighbourhood of Kigezi itself
(*Robin Kemp*).

KALIELLA IREDALEI, sp. n. (Pl. XXXI. fig. 12.)

Shell rimate, small, conically turbate, light reddish brown; whorls 6, rather convex, the last *not carinate at the periphery*, sculptured with very fine, somewhat oblique, transverse striae; base of shell marked with lines of growth and sculptured with slightly distant, fine, wavy striae; suture well impressed, *not margined*; umbilicus very narrow, partly concealed by the outward expansion of the columella; columella outwardly expanded, vertically descending in a gentle curve above, oblique below; labrum simple; aperture sublunate.

Alt. 2.5, diam. maj. 2.75, diam. min. 2.5 mm.

Hab. Between the Igembi Hills and Nyeri, British East Africa
(*Robin Kemp*).

The very characteristic sculpture of this pretty little species is only visible under the microscope.

SITALA IREDALEI, sp. n. (Pl. XXXI. fig. 15.)

Shell rather acuminate turbate, with convex base, pale greyish yellow; whorls 6, somewhat rapidly increasing, the last inflated, sculptured with microscopic, spiral striae and oblique, transverse riblets or creases; suture impressed; columella vertically descending, slightly angled below; aperture ovate.

Alt. 4.25, diam. maj. 4.25 mm.

Aperture: alt. 2, diam. 1.75 mm.

Hab. Mt. Kenangop, Aberdare Range, British East Africa
(*Robin Kemp*).

TRACHYCYSTIS IREDALEI, sp. n. (Pl. XXXII. figs. 8, 8 a, 8 b.)

Shell small, depressedly suborbicular, almost planulate, reddish brown; whorls 3, the apical whorl large, smooth, the remainder sculptured throughout with rather fine and closely-set, obliquely arcuate, transverse costulae, between which occur very fine, transverse striae, crossed by extremely fine spirals, both these last and the transverse striae being only visible with the aid of the microscope; suture well impressed; umbilicus very wide and

rather deep; columella very oblique; labrum simple; aperture broadly sublunate.

Alt. .75, diam. maj. 2, diam. min. 1.75 mm.

Hab. Between the Igembi Hills and Nyeri, British East Africa (*Robin Kemp*).

LEUCOCHILOIDES CHANLERENSIS, sp. n. (Pl. XXXI. fig. 16.)

Shell small, rimate, cylindrically fusiform, slightly shining, reddish brown; whorls 5, regularly increasing, the last ascending in front, marked with oblique, transverse growth-lines; suture well impressed; umbilicus very narrow; columella curved; labrum rather narrowly expanded, whitish, not reflexed; aperture sub-circular, bearing a single, nodulous denticle just below the point of insertion of the labrum with the parietal wall.

Alt. nearly 4, diam. maj. 1.75 mm.

Aperture: alt. .75, diam. nearly .75 mm.

Hab. Chanler Falls, Eusso Nyiro, British East Africa (*Robin Kemp*).

LEUCOCHILOIDES IREDALEI, sp. n. (Pl. XXXI. fig. 18.)

Shell differing from *L. chanlerensis* in its blunter form, more swollen whorls, deeper suture, more open umbilicus, straighter columella, and narrower and more erect labrum; moreover, it lacks the nodulous denticle which in the present species is replaced by an *erect* white denticle situate *low down on the parietal wall* well within the aperture, and a smaller erect squarish denticle on the columella also situate well within the opening.

Alt. 3.5, diam. maj. 1.75 mm.

Aperture: alt. .75, diam. nearly .75 mm.

Hab. Eusso Nyiro, British East Africa (*Robin Kemp*).

LEUCOCHILOIDES SOROR, sp. n. (Pl. XXXI. fig. 17.)

Very closely allied to *L. chanlerensis* and possibly only a variety of that species; it differs, however, in its larger size, more open umbilicus, though having a proportionately narrower base, and in having an additional whorl, the aperture is also more ovate than is the case in that species.

Alt. 6, diam. maj. 2.25 mm.

Aperture: alt. 1.5, diam. 1.25 mm.

Hab. Chanler Falls, Eusso Nyiro, British East Africa (*Robin Kemp*).

LEUCOCHILOIDES GAZIENSIS, sp. n. (Pl. XXXI. fig. 19.)

Shell small, ovately fusiform, pale reddish brown; whorls 5, convex, marked with fine, oblique, transverse striæ; suture deeply impressed; umbilical area broadly depressed; labrum with converging upper margin, white, rather broadly expanded; aperture ovate.

Alt. nearly 4.5, diam. maj. 2.25, diam. min. 2 mm.

Aperture: alt. 1, diam. .5 mm.

Hab. Gazi, British East Africa (*Robin Kemp*).

ALÆA KENIANA, sp. n. (Pl. XXXI. fig. 6.)

Shell minute, cylindrically ovate with very obtuse apex, scarcely rimate, moderately thin, pale reddish chestnut; whorls 4, convex, shouldered above, marked with fine, oblique, transverse striae and slightly malleated; suture well impressed; columella whitish, internally broad; labrum erectly reflexed, the margins joined by a thin whitish callus; aperture very broadly inversely auriform.

Alt. 2, diam. maj. 2.25 mm.

Hab. Mt. Kenia, at an altitude of from 6000 to 9000 ft. (*Robin Kemp*).

HOMORUS IREDALEI, sp. n. (Pl. XXXI. fig. 10.)

Shell moderately large, subulately fusiform, with minute apex, covered with a yellowish periostracum, on the lower whorls closely, obliquely, transversely banded with dark blackish purple; whorls 10, flattened, the first minute, the second proportionately large, the remainder regularly increasing, smooth but for lines of growth; suture lightly impressed, faintly crenellate below; columella short, gently curved, abruptly truncate, diffused above into a thickish, well-defined callus which reaches the upper margin of the labrum; labrum simple; aperture elongately ovate.

Alt. 31.25, diam. maj. 9.25 mm.

Aperture: alt. 8.5, diam. 4.5 mm.

Hab. Between Mbarara and Kigezi, extreme S.W. Uganda (*Robin Kemp*).

SUCCINEA KEMPI, sp. n. (Pl. XXXII. figs. 2, 2*a*.)

Shell ovate, opaque, cream-coloured; remaining whorls 2, the first very small, the last comparatively very large, marked only with lines of growth; suture impressed, broadly margined below; columella very obliquely curved; labrum simple, acute; aperture dilated, ovate.

Alt. 7.25, diam. maj. 5.5, diam. min. 3.25 mm.

Aperture: alt. 6, diam. 4 mm.

Hab. Between Entebbe and Mbarara, S.W. Uganda (*Robin Kemp*).

A remarkable form, easily recognizable by its minute spire and enormously large last whorl.

SUCCINEA PRINCEI, sp. n. (Pl. XXXII. figs. 3, 3*a*.)

Shell ovately fusiform, very thin, pale yellowish horn-colour; whorls 2½, the last very long, polished, smooth but for lines of growth; columella arched; aperture dilated, very large.

Alt. 7.25, diam. maj. 3.5 mm.

Aperture: alt. 5, diam. 2.5 mm.

Hab. Nakuru, British East Africa (*Robin Kemp*).

BLAUNERIA EXSILIUM, sp. n. (Pl. XXXI. fig. 8.)

Shell subulate, thin, pale yellowish horn-colour; whorls 8, smooth but for lines of growth, polished, shining, flat; suture

linear, broadly margined below; columella arched, white, extending into a thick, white, narrow, well-defined callus, bearing a single plait above, obliquely truncate below; labrum acute, whitish; aperture narrowly inversely auriform.

Alt. 4·5, diam. maj. 1·25 mm.

Aperture: alt. 1·5, diam. ·5 mm.

Hab. Gazi, British East Africa (*Robin Kemp*).

ANCYLUS KEMPI, sp. n. (Pl. XXXI. figs. 2, 2 a.)

Shell rectangularly ovate, depressed, somewhat sinuous on the left side, with subcentral apex, olive-brown, marked with concentric growth-lines, and indistinctly sculptured towards the margin with faint, radiate striæ, which are more visible on the interior surface of the shell; margin acute; interior of shell polished, shining, pale brown.

Alt. 1·25, diam. maj. 4·25, diam. min. 3·25 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

LIMNÆA KEMPI, sp. n. (Pl. XXXII. fig. 1.)

Shell small, ovately fusiform, thin, pale reddish brown; whorls 3, the last large and somewhat elongate, marked with fine, silky, transverse growth-striæ; suture well impressed; columella obliquely descending, not twisted or arched above, diffused into a very thin, well-defined, parietal callus which reaches the upper margin of the labrum; labrum simple, acute, somewhat dilated at the base; aperture very elongately ovate.

Alt. 7·5, diam. maj. 4 mm.

Aperture: alt. 5, diam. 2·5 mm.

Hab. Kisumi, Lake Victoria Nyanza, British East Africa (*Robin Kemp*).

PLANORBIS KIGEZIENSIS, sp. n. (Pl. XXXII. figs. 5, 5 a, 5 b.)

Shell small, depressed, suborbicular, with concave spire, thin, pale greenish grey; whorls 4, regularly and rather rapidly increasing, the last obtusely angled above, somewhat sharply angled below, sculptured with fine, closely-set, arcuate, transverse striæ; suture well impressed; base of shell not very convex; umbilical depression very wide, shallow; columella descending very obliquely and diffused above into a projecting callus which reaches the upper margin of the labrum; labrum simple, acute, projecting in front, receding above and below, the margins converging; aperture subelliptical.

Alt. 1, diam. maj. nearly 3·5, diam. min. 3 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

PLANORBIS SPERABILIS, sp. n. (Pl. XXXII. figs. 4, 4 a, 4 b.)

Shell very small, depressedly orbicular, thin, greyish-yellow horn-colour; whorls 3, rather rapidly increasing, marked with

somewhat strong, radiate growth-lines; base of shell slightly concave; labrum receding below, the margins joined by a thin callus; aperture subcircular.

Alt. nearly .5, diam. maj. nearly 2, diam. min. 1.5 mm.

Aperture: alt. .25, diam. .25 mm.

Hab. Gazi, British East Africa (*Robin Kemp*).

SEGMENTINA EUSSOENSIS, sp. n. (Pl. XXXII. figs. 6, 6a, 6b.)

Shell depressedly orbicular, with concave spire and almost planulate base, pale yellowish wax-colour, polished, somewhat shining; whorls $4\frac{1}{2}$, rapidly increasing, the last large and rounded, angled above and bluntly carinate at the periphery, below which the base of the shell is nearly flat; suture rather lightly impressed, margined below; umbilicus wide, shallow; labrum thin, rapidly receding below; aperture depressedly and angularly sublunate.

Alt. 1.5, diam. maj. 5.25, diam. min. 4.75 mm.

Aperture: alt. 1.25, diam. 1 mm.

Hab. Chandler Falls, Eusso Nyiro, British East Africa (*Robin Kemp*).

SEGMENTINA KEMPI, sp. n. (Pl. XXXII. figs. 7, 7a, 7b.)

Shell small, suborbicular, planulate above and below, with concave spire, white, polished, shining; whorls 4, the first three small, regularly increasing, the last very large, rounded above, sharply angular below, indistinctly sculptured with microscopic, silky, transverse striae; suture impressed, irregular; umbilicus moderately narrow, and deep; columella obliquely descending, angled below, extending above into a parietal callus which joins the upper or sutural margin of the last whorl well within the shell; labrum acute, receding below; aperture triangular.

Alt. 1, diam. maj. 3.75, diam. min. 2.25 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

VIVIPARA RUBICUNDA, v. Martens, var. KISUMIENSIS, var. n. (Pl. XXXII. fig. 9.)

Shell differing from the typical form in its larger size, darker colour, and in being proportionately higher and narrower, the aperture is also more ovate and the peristome edged with black.

Alt. 28, diam. maj. 15.75, diam. min. 12 mm.

Aperture: alt. 10, diam. 7 mm.

Hab. Kisumi, Lake Victoria Nyanza, British East Africa (*Robin Kemp*).

ASSIMANIA AURIFERA, sp. n. (Pl. XXXI. fig. 9.)

Shell turbinate, perforate, thin, semitransparent, dark brownish horn-colour, minutely and densely freckled with golden yellow; whorls $5\frac{1}{2}$, regularly increasing, shouldered above, convex, very minutely spirally striate; suture well impressed; umbilicus moderately wide, deep; columella very oblique, obtuse-angled,

slightly outwardly reflexed; labrum simple, acute; aperture irregularly roundly ovate.

Alt. 3·75, diam. maj. 2·75 mm.

Aperture: alt. 1·5, diam. 1 mm.

Hab. Gazi, British East Africa (*Robin Kemp*).

EUSSOIA, gen. n.

Shell solid, conical, resembling *Assimania*, but without operculum, though fluviatile in its habits.

Type of genus, *E. inopina*.

The genus, as above stated, bears a great resemblance to *Assimania*, but though I have been able to examine a large number of specimens collected alive, and which still contained the decaying animal, I have been unable to find any trace of operculum: moreover, on physiographical grounds alone, I should be loth to refer it to that genus, which is essentially a coast form, whereas the point at which the present specimens were collected is at least 375 miles from the nearest point on the African sea-board, and it is extremely probable, judging by the maps at my disposal, that the connection by water between the locality where the present species was collected and the sea is very much more than that distance; the Eusso Nyiro after flowing through Lake Lorian, is at present believed to flow out of that lake as the Lakojira River, a tributary of the Juba, which it joins not far from its mouth and which forms the north-eastern boundary-line between British East Africa and Italian Somaliland.

Pending the examination of the animal, which in the specimens sent home by Mr. Kemp was not in sufficiently good condition for dissectional purposes, I propose to place the genus temporarily in the vicinity of the Assimanieidæ.

EUSSOIA INOPINA, sp. n. (Pl. XXXII. fig. 10.)

Shell small, rimate, turbinately conic, dark reddish brown; whorls $5\frac{1}{2}$, regularly increasing, flattish, except the last, which is somewhat globose, marked only with transverse growth-lines; suture impressed; umbilicus very narrow, almost covered by the dilation of the columella; columella descending in a rounded curve, rather erectly dilated, diffused above into a thin, parietal callus; labrum simple; aperture subovate.

Alt. 3·5, diam. maj. 2·5, diam. min. 2 mm.

Aperture: alt. 1·75, diam. 1·25 mm.

Hab. Banks of the Eusso Nyiro River, British East Africa (*Robin Kemp*).

SPHÆRIUM KIGEZIENSIS, sp. n. (Pl. XXXI. figs. 1, 1 a.)

Shell very small, triangularly ovate, yellowish red; both valves closely concentrically striate, the striæ being rather coarser towards the umbonal region; umbones rather large, not prominent; dorsal margin sharply arched; ventral margin gently rounded; anterior side rather abruptly descending; posterior side subrostrate, somewhat angularly rounded; cardinal tooth in right

valve small, oblique, slightly notched anteriorly; cardinal teeth in left valve very small, converging; lateral teeth in right valve very weak, in left valve weak, somewhat curved; scars very lightly impressed; interior of shell somewhat granular.

Long. 3, lat. 3.5 mm.

Hab. Kigezi, extreme S.W. Uganda, at an altitude of 6000 ft. (*Robin Kemp*).

EXPLANATION OF THE PLATES.

PLATE XXXI.

- Fig. 1. *Sphærium kigeziensis*, $\times 5$.
 1 a. " " hinge, $\times 5$.
 2 & 2 a. *Ancylus kemp*, $\times 5$.
 3. *Africarium kemp*, nat. size.
 4. " *microstriata*, $\times 1\frac{1}{2}$.
 4 a. " " sculpture, $\times 12$.
 5. " *microgranulata*, $\times 1\frac{1}{2}$.
 5 a. " " sculpture, $\times 12$.
 6. *Alæa keniana*, $\times 10$.
 7. *Ennea microstriata*, $\times 2\frac{1}{2}$.
 8. *Blanneria exsilium*, $\times 5$.
 9. *Assimania aurifera*, $\times 6$.
 10. *Homorus iredalei*, nat. size.
 11. *Kaliella consobrina*, $\times 6$.
 12. " *iredalei*, $\times 6$.
 13. " *depauperata*, $\times 6$.
 13 a. " " sculpture, $\times 12$.
 14. " *kigeziensis*, $\times 6$.
 15. *Sitala iredalei*, $\times 4$.
 16. *Leucochiloides chanlerensis*, $\times 7$.
 17. " *soror*, $\times 4$.
 18. " *iredalei*, $\times 7$.
 19. " *gaziensis*, $\times 6$.
 20. *Natalina permembranacea*, $\times 1\frac{1}{2}$.
 20 a. " " spire, $\times 1\frac{1}{2}$.
 20 b. " " base, $\times 1\frac{1}{2}$.

PLATE XXXII.

- Fig. 1. *Limnæa kemp*, $\times 3$.
 2 & 2 a. *Succinea kemp*, $\times 2\frac{1}{2}$.
 3 & 3 a. " *princei*, $\times 2\frac{1}{2}$.
 4. *Planorbis sperabilis*, $\times 8$.
 4 a. " " spire, $\times 8$.
 4 b. " " base, $\times 8$.
 5. " *kigeziensis*, $\times 6$.
 5 a. " " spire, $\times 6$.
 5 b. " " base, $\times 6$.
 6. *Segmentina eussoensis*, $\times 3$.
 6 a. " " spire, $\times 3$.
 6 b. " " base, $\times 3$.
 7. " *kemp*, $\times 6$.
 7 a. " " spire, $\times 6$.
 7 b. " " base, $\times 6$.
 8. *Trachycystis iredalei*, $\times 8$.
 8 a. " " spire, $\times 8$.
 8 b. " " base, $\times 8$.
 9. *Vivipara rubicunda*, var. *kisumiensis*, nat. size.
 10. *Eussoia inopina*, $\times 5$.
 11. *Vittrina compacta*, $\times 2$.
 12. *Thapsiella millestriata*, $\times 2$.
 13. " *opposita*, $\times 8$.
 14. *Zingis kemp*, $\times 4$.
 15. " *papyracea*, $\times 1\frac{1}{2}$.
 16. " *planispira*, $\times 1\frac{1}{2}$.

13. Contributions to the Anatomy and Systematic Arrangement of the Cestoidea. By FRANK E. BEDDARD, M.A., F.R.S., F.Z.S., Prosector to the Society.

[Received November 1, 1911: Read November 21, 1911.]

(Text-figures 19-30.)

III. ON A NEW GENUS OF TAPEWORMS (*Otiditænia*) FROM THE BUSTARD (*Eupodotis kori*).

An example of the South-African Bustard (*Eupodotis kori*) on April 27th, 1911, voided a number of white curiously-shaped bodies, the nature of which I did not recognise until they were submitted to microscopic examination. The shape of these bodies may be learnt by an inspection of text-figure 19. They are separate mature proglottids of a tapeworm, of which I obtained complete specimens later (on May 7th), when the bird died. Since the Bustard was acquired by the Society on October 1st, 1910, it seems likely that the infection did not take place in the Society's Gardens, but that the parasites were already present when the bird arrived.

Text-fig. 19.



Ripe and detached proglottids of *Otiditænia eupodotidis*.

A most useful and presumably comprehensive list of the tapeworms of birds has been quite recently published by Prof. Fuhrmann*. From this it would appear that only the following species have been found in the Otidiformes, and that none at all have been met with in *Eupodotis kori*—if it has been examined from this

* "Die Cestoden der Vögel," Zool. Jahrb. 1908, Suppl.-Bd. x.

point of view. The species are *Idiogenes otidis*, *Chapmannia lapicu*, *Hymenolepis villosa*, *H. tetracis*, and *H. ambiguus*. There is no doubt that the species which forms the subject of the present communication to the Society is none of these; nor can I reconcile its characters with those of any other genus of Tapeworms of the group Tetracotylea (of which group it is undoubtedly a member) which have been described up to the present. I shall, however, defer the attempt to fix its systematic position until I have described its anatomical characters.

I have examined four complete specimens of this worm, besides some fragments which may or may not have belonged to those specimens. The largest was about 3 inches in length, and the greatest diameter of the posterior segments was 4 mm. The diameter of the body gradually increases from the head up to the point of greatest diameter, and then remains the same; there is not, as in so many tapeworms, a narrow anterior region of the body, which suddenly widens within the limits of two or three proglottids. The general shape is thus much like that of certain species of *Bertiella*, for example of *B. cercopitheci**. There is, however, no further resemblance between the present genus and *Bertiella* in external form. The worm is white in colour; but there is some black pigment in the head behind the suckers, and the ripe proglottids are of a brick-red hue.

The *scolex* of this new worm—for which I propose the generic and specific names of *Otiditenia eupodotidis*, as indicative of its habitat—is not particularly small nor, on the other hand, conspicuous by its large size. I have not found the least trace of hooks anywhere on the suckers. The head seems to be completely unarmed as to the suckers, but the rostellum has hooks.

The four *suckers* are, as is so often the case, extremely mobile, and can be protruded a long way from the head as cylindrical processes. In this case they look rather forwards than outwards. When retracted and in a normal condition the suckers look outwards and slightly upwards. When fully protruded the suckers give to the head of this worm an appearance very like that of the genus of Tetraphyllidea, *Cylindrophorus*†.

I have investigated the structure of the rostellum and lateral suckers by transverse sections through the head. There is nothing remarkable about the structure of the suckers. The *rostellum*, however, demands some consideration. When the worm is examined with a lens or with a low power only of the microscope, the appearance presented is that of a median sucker such as occurs sometimes, though, as it is stated by Küchenmeister‡, not always, in *Tænia saginata*. The hooks are, in fact, so minute that I was unable to detect them when studying the worm in that fashion. Nor can they be detected save with high-powered lenses. The varying condition of the retraction of the median sucker, or rather

* See Beddard, P. Z. S. 1911, p. 640, text-fig. 151.

† Bronn's 'Klassen u. Ordnungen des Thierreichs,' Bd. iv. Taf. 42. fig. 14.

‡ 'Die Parasiten des Menschen,' Leipsic 1881, p. 140, pl. ii. fig. 3.

rostellum, renders it apparently absent or more feebly developed in some individuals than in others. And there is here a resemblance to the otherwise not closely allied *Tænia saginata*.

This median sucker is, indeed, a not much more developed structure than the rudimentary rostellum of *Tænia saginata*. In this latter species Railliet* speaks of "le rostre faisant défaut et se trouvant remplacé fréquemment par une légère dépression"; while Leuckart †, in defining the species, states that "the head has a flattened crown with a pit-like hollow in the middle." On the other hand, Küchenmeister, while emphasizing the occasional absence of any such depression in both text and figure, also figures ‡ an organ very like a sucker, and certainly more than a mere depression. The structure, however, is not, according to Leuckart §, a sucker, but a rudimentary rostellum with a distinct lenticular muscular mass. Leuckart's figure of a section through this "sucker" is copied in Bronn's 'Thierreichs' (Bd. iv. p. 1203).

The accompanying text-figure (text-fig. 20) shows a median longitudinal section through the scolex of *Otiditenia*, illustrating the rudimentary rostellum and enabling it to be compared with the adjacent suckers. The simplicity of the really sucker-like rostellum will be apparent from this figure, which represents the rostellum in a contracted state withdrawn into the scolex. Inasmuch as the setæ border the rostellum in a double circle, they are not visible in such a preparation, only one or two being seen in each section at the two corners of the rostellum. The rostellum itself is obviously (to my mind) no more, or very little more, developed than that of *Tænia saginata*, already referred to; its muscular layer is not thicker than that of the suckers, as will be seen from my figure. This obviously contrasts greatly with complicated and more typical rostellæ ||.

It will be observed, moreover, that the floor of the cavity into which the rostellum is retractile—which floor constitutes the rostellum—is hardly, if at all, thicker than the lateral walls of the cavity; that the whole structure, in fact, does not greatly differ from a sucker. It may be borne in mind that this is a possible origin of the rostellum, though the theory that it is the metamorphosed remains of a pharynx has been put forward. On the other hand, the nuclei are more densely packed in the rostellum than in the suckers, as the figure referred to shows. This difference is, however, perhaps partly due to the more contracted condition of the rostellum, and possibly also to its greater contractility. Again, the layer of chitin covering the rostellum is very much thicker than that which lines the suckers—the latter being, indeed, inappreciable. There is some black pigment in the head behind the suckers.

My preparations unfortunately do not allow me to give any

* 'Traité de Zoologie Médicale et Agricole,' ed. 2, Paris 1895, p. 232.

† 'The Parasites of Man' (Engl. ed. transl. by Hoyle), Edinburgh 1886, p. 407.

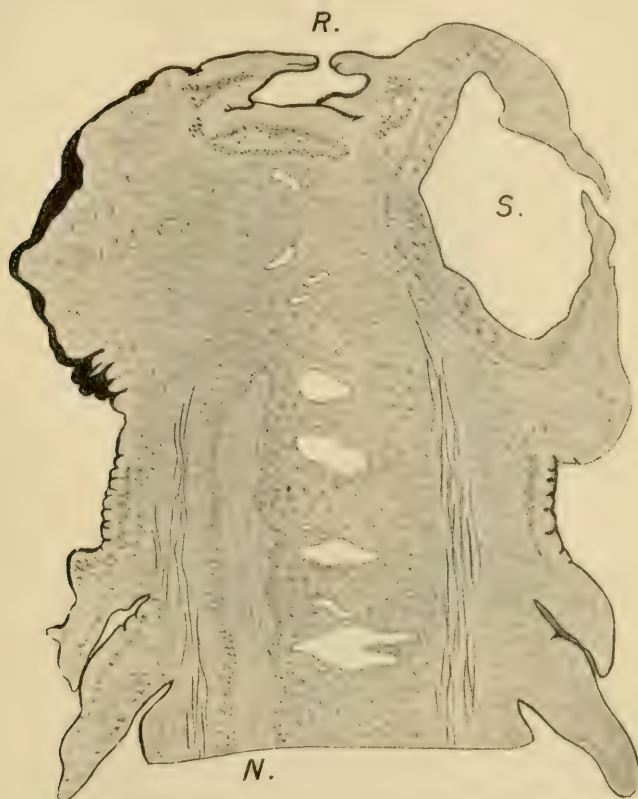
‡ *Loc. cit.* pl. vi. fig. 8.

§ *Loc. cit.* p. 435.

|| *Cf.*, e. g., Bronn's 'Thierreichs,' Bd. iv. figs. 56, 57, 58, pp. 1326-1328.

accurate account or figures of the rostellar hooks. I can only say that they are curved and hook-like, *not* straight, and very numerous, certainly at least 150 in number, and probably more, and that they are disposed in an alternating fashion, forming a double crown.

Text-fig. 20.

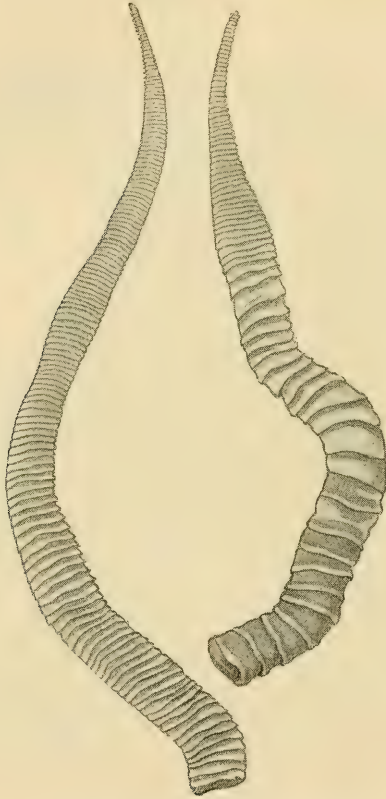
Longitudinal section through scolex of *Otoditænia eupodotidis*.

R. Rudimentary rostellum (the hooks are too small to appear). *S.* One or the suckers. *N.* Lateral nerve-cord of one side.

The longitudinal section from which the annexed text-figure of the rostellum was drawn also shows very well the existence of a neck in this tapeworm. It varies much in length, though it is never longer than the length of three or four proglottids immediately following upon it. On the other hand, it is sometimes very short, not more than the length of the first proglottid. If this had not been observed in the living worm, where the neck is much more distinct, as such, from the proglottids than in alcohol-

preserved material, it might easily be supposed that this species was characterised by the absence of a neck. Such a mistake may have been made with other species.

Text-fig. 21.

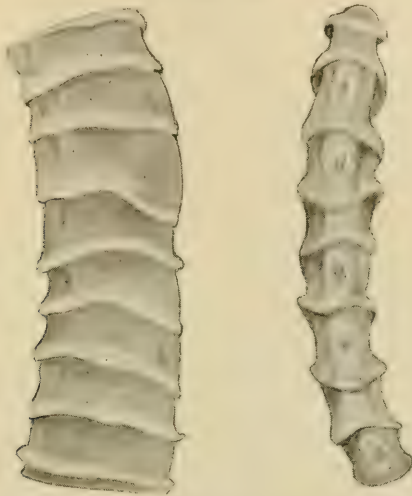


Two examples of *Otiditænia eupoditidis* differing slightly in progressive increase of size of proglottids.

The general character of the segmentation and the form of the individual proglottids is shown in text-figure 21, which represents two individuals which are slightly different in these characters. In one of them the segments increase in length more rapidly than in the other; but in neither are the posterior segments longer than they are broad. Nor do they even get to be so long, except in the case of the detached proglottids. As the segments advance towards maturity the projection of one segment over that which follows is seen to be more marked, and it forms quite a sharp-edged frill, as is shown in the drawings referred to. The completely

mature proglottids are represented in several aspects in text-figure 19 (p. 194). These proglottids, as there depicted, have a very peculiar form, and have quite lost the flattened appearance of the anterior region of the strobila. They are, indeed, almost spherical in general outline. The projecting frill remains, but its edges are closely adpressed. A single proglottid presents much the appearance of a full sack with the lips of the mouth closely drawn together.

Text-fig. 22.



Left-hand figure a ventral view of eight nearly mature proglottids of *Otoditania eupodotidis*.

Right-hand figure a lateral view of the same showing genital pores.

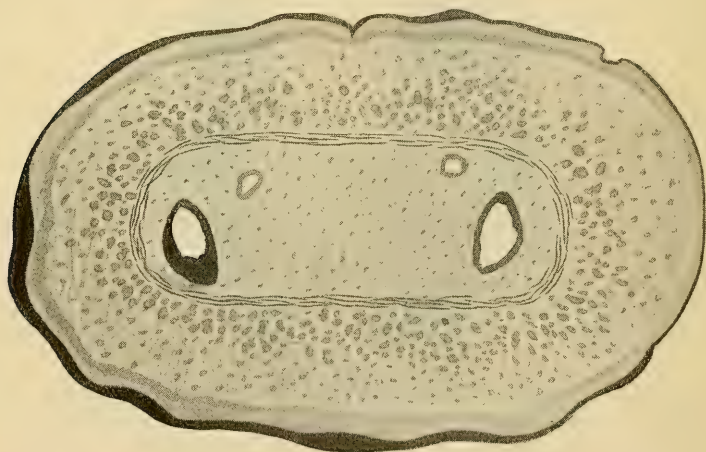
The last external character to be noticed is the position and character of the genital pores. These are irregularly alternate. The pores are simple orifices upon the lateral surfaces of the proglottids, and are not in any way prolonged into a spout-like outgrowth. They are, however, situated on an area which covers the whole of the lateral face of the segment, and is slightly raised; it is also whiter in colour than the rest of the (rather yellowish) body. Finally, the segment is longer from before backwards on the side which bears the genital pore; this inequality of the two sides of a segment enables the position of a genital pore to be fixed without actually inspecting the orifice (text-fig. 22).

In transverse sections of the body before the reproductive organs are to be seen, except in rudiment, the cortical parenchyma will be observed to be fully as thick as the medullary parenchyma. Indeed, anteriorly in the segment before the overlapping frill has detached itself the cortical parenchyma is actually the thicker. The longitudinal muscle-fibres seen in this layer are disposed

singly in the more peripheral regions; more centrally they are aggregated into bundles, the number of fibres being larger in the deeper strata. In the largest I have counted 14 or 15 fibres. Within this layer and bounding the medullary parenchyma is a layer of delicate circular fibres. In older proglottids the number of longitudinal fibres to a bundle may be considerably greater and the strength of the circular layer has increased. This latter fact is particularly to be noted in the segments which are nearly ready for detachment.

The *water vascular tubes* are the usual four longitudinal trunks, of which—as is again usual—the dorsal is smaller and has much thicker walls. The larger ventral tubes are connected by a rather wide commissural vessel in each segment. The dorsal vessels are apt to vary a little in their relation to the ventral vessels; but they are never superposed, *i. e.* directly dorsal and ventral to each other. The dorsal vessel, in fact, lies to the inside of the ventral

Text-fig. 23.



Transverse section through an immature proglottid of *Otoditenia eupodotidis*.

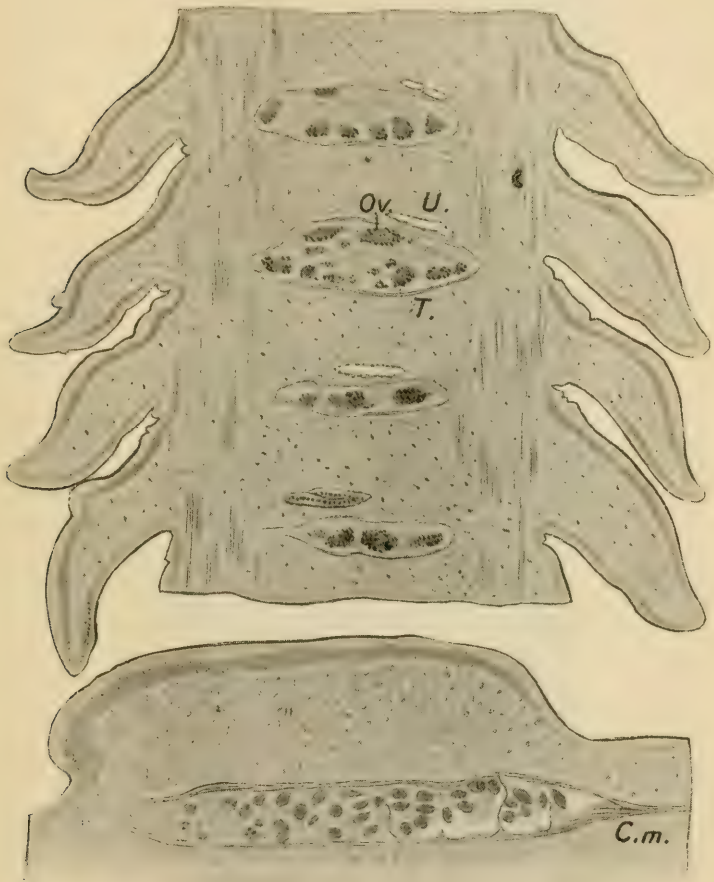
The larger ventral water vascular tubes lie below and rather to the outside of the smaller dorsal vessels.

vessel, sometimes absolutely parallel with it and sometimes more dorsally inclined. The capacity of the large ventral vessel tends to vary; I have seen it to be almost obliterated for a short space. In the anterior segments of the body there is much less difference in calibre between the water vascular vessels than is to be seen later.

The *testes* of this tapeworm lie quite posteriorly in the segment, and thus behind all the other parts of the generative system. In sagittal sections of young proglottids in which the testes are mature or nearly so, but in which the uterus is not yet much

developed, a straight line joining the posterior angles formed by the outgrowths of the segments dorsally and ventrally is just in contact with the posterior boundary of the mass of testes. Anteriorly they are well separated from, though very close to, the ovaries. The testes, in fact, in the genus described in the present paper do not straggle over the segment as they are represented to

Text-fig. 24.



Upper figure a horizontal section through four not completely ripe proglottids of *Otiditænia eupodotidis*.

Ov. Ovary. T. Mass of testes. U. Uterus.

Lower figure a portion of a transverse section through a proglottid, showing the division of the layer of circular muscles (C.m.) to enclose the young uterus.

do in the allied genus *Choanotænia*—for example, in the species *Ch. galbula* and *Ch. infundibulum* figured by Cohn*.

Text-fig. 25.



Horizontal section through three not fully mature proglottids of
Otiditænia eupodotidis.

d. Dorsal water vascular tube. *W.* Ventral ditto. *T.* Mass of testes.
U. Uterus.

* "Zur Anatomie etc. der Vogelcestoden." Nova Acta Ac. Nat. Curios. lxxix. 1901
pl. 31. fig. 40 & pl. 32. fig. 47.

The testes of *Otiditania* (text-fig. 24, p. 201) form, in fact, a very compact mass, which almost suggests a single organ whose compactness and general characters form a very distinguishing mark of this genus. In the sagittal sections already referred to, the mass of testes is seen to form a band rather lenticular in outline, *i. e.* tapering dorsally and ventrally, which extends without intermission from the dorsal to the ventral muscular body-wall. In transverse sections of the worm the testicular mass is seen equally well to form an unbroken dorso-ventral layer occupying the whole of the central parenchyma between the larger ventral water vascular vessels, to the outside of which the testes do not extend. The wall of testes which thus exists—marking, as has already been said, the posterior region of the proglottid—is a very thin one. It is formed of only a single layer or in parts of two layers of testes.

In their general form the testes are oval. The very small amount of space occupied by the testes in an antero-posterior plane is striking; but it is greater in the less fully than in the more fully mature proglottids. In the former the antero-posterior diameter of the group of testes is a little more than one-third of the length of the segment; in the latter perhaps one-tenth, and the disproportion becomes even greater in absolutely ripe segments, where, indeed, the testes finally disappear, being apparently pressed out of existence by the swelling proglottids.

In such tapeworms as I am acquainted with by first-hand knowledge the testes are scattered in the medullary parenchyma, though often closely adpressed; but there is no particular modification of the medullary parenchyma in the region occupied by the testes. The same conditions appear to obtain in many forms described by others.

In *Otiditania*, however, the testes lie in a very distinct cavity, which has in sagittal sections of the entire proglottid a lenticular outline already mentioned. This cavity is not everywhere apparent as actual spaces lying outside of the testes; it is for the most part filled up with an interstitial tissue, which separates the individual testes and in which they lie closely packed together. Although this interstitial tissue is not very different in appearance from the medullary parenchyma, it is separated from it by a distinct boundary-line and is more faintly stained by carmine, and does not seem to contain any calcareous corpuscles. The distinctness of the mass of testes, as a whole, from the surrounding regions of the proglottid will be apparent from text-figure 26 (p. 204). Here and there the interstitial tissue seems to be replaced by actual cavities which contain no fluid that takes a stain. They appear, in fact, to be empty.

Since the testes lie quite posteriorly in the segments, it is obvious that they must be close to the transverse vessels of the water vascular system, which unite the ventral vessels. The spaces to which I have referred, I believe, entirely belong to the transverse water vascular trunks which are large in the

present species. Though the individual testes appear at first sight to be actually bathed by the fluid of the excretory tube, a more careful examination has always shown a layer of interstitial tissue separating the actual testes from the water vascular spaces. The testes, however, do project with their covering into the spaces (see text-fig. 25, p. 202) here and there, and there is thus a very close anatomical relation between them.

Text-fig. 26.



Sagittal section through three proglottids of *Otiditenia eupodotidis*.

T. Mass of testes. U. Uterus.

In longitudinal horizontal sections (text-fig. 25) it is obvious that the testes of *Otiditenia* form a layer which is, as a rule, only one thick, though here and there two testes lie one in front of the other. The distinction between the interstitial tissue separating

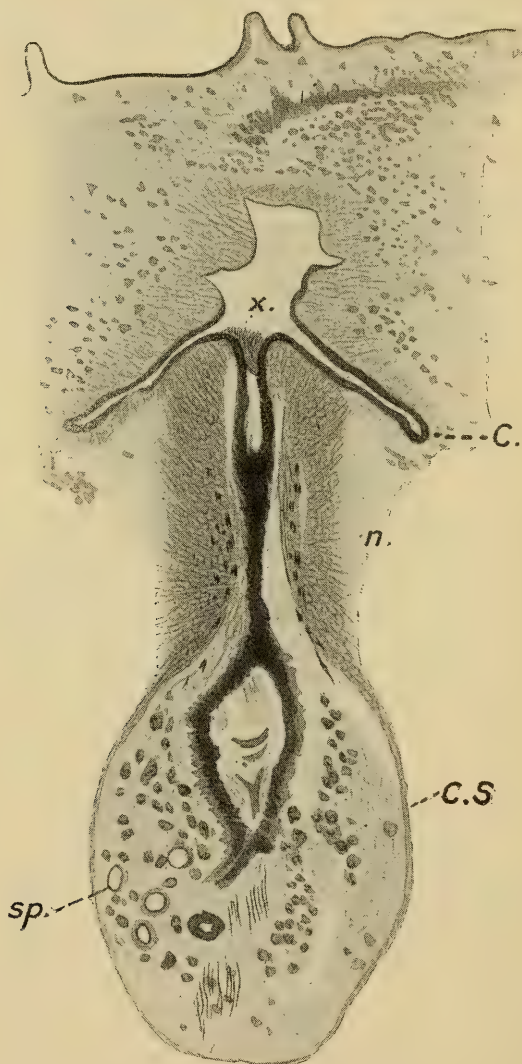
the individual testes and the general medullary parenchyma is strikingly obvious in such sections, inasmuch as the whole area can be seen in a single section extending from one side of the body to the other. Such sections also show particularly well the fact that the testes extend rather beyond the large ventral water vascular vessel on the fore side, where, indeed, they occasionally nearly touch the outer skin. The extension is not quite so great on the opposite side, though the mass of testes usually bulges into the vessel, and, as already mentioned, presents very much the appearance of lying in it. It is to be noticed also that in these lateral extensions of the testes the whole mass gets very much wider from back to front, the testes being three or four deep. These outgrowths intrench upon the area occupied by the coils of the vas deferens, and push laterally and flatten out that coil. The extension of this testicular mass laterally is highly suggestive of its being a single organ growing as a whole and not merely an association of separate and quite individualized testes. The interstitial substance which divides the testes presents the appearance in the direction of its fibrils of having flowed laterally, carrying with it the enclosed testes. Multiplying the 30 or so testes which are visible in a horizontal section by the 6 or 7 which are visible in a sagittal section, we get a total of 200 or so, which may be slightly increased to include the testes found in the lateral extensions of the testicular area just referred to.

The ovaries are very obvious in the segments where they occur; but they disappear early in the strobila and are represented thenceforward by mere vestiges. The ovaries are to the fore side of the segment and closer to that margin of the strobila than the vitelline gland, to which, however, they are closely contiguous. They commence on the level of the receptaculum and lie on both dorsal and ventral sides of that portion of the oviducal tube, hence getting a double character—the ventral half (or more ventral ovary, if we speak of two) is considerably the larger. They lie posteriorly in the segment, but between the testes and the uterus. They by no means occupy the whole breadth of the medullary parenchyma in a sagittal section, as do the testes when fully developed.

The *cloaca genitalis* opens on to the exterior directly. There is no papilla-like process bearing a genital orifice. As already mentioned, the pores are irregularly alternate in position, and I have seen as many as six consecutive pores on the same side of the body. The cavity of this conjoined region of the genital ducts is rather wide and of some length; the lumen is slit-like to circular, but the walls never seem to be crumpled so as to give a star-like appearance to the lumen. The cavity is lined by a very thick layer of cuticle which stains very deeply in carmine. The walls of the cloaca genitalis contain at some little distance from the chitinous lining a sheath of loosely packed large muscle-fibres, which completely encircle the tube and run in a longitudinal direction. The fibres form several layers when seen in transverse

section, and are very conspicuous on account of their deep staining with carmine. The cloaca genitalis is very nearly as deep as

Text-fig. 27.



Cirrus sac of *Otiditenia eupodotidis*.

C. Extensions of genital cloaca. C.S. Expanded region of cirrus sac. n. Narrow region of sperm-duct. x in genital cloaca points to spines on "penis."

the length of the cirrus sac. When the entire system of genital ducts is seen in longitudinal section, *i. e.* in transverse sections of the proglottid, it will be observed that the cirrus sac projects into the cloaca genitalis, and that the latter is therefore prolonged backwards as a kind of collar surrounding the protrusible part of the cirrus sac. Dr. Gough has figured in *Stilesia hepatica** a similar backward growth of the cavity of the cloaca genitalis. In such longitudinal sections of the cloaca genitalis of *Otiditenia* it will be observed that the cavity is not so regular as I have seen it in transverse sections; there are lateral foldings of the lumen which are probably paired and thus produce no appearance of crumpling when the organ is viewed in transverse sections.

The vagina and cirrus sac, of course, open into this cloaca, the vagina nearer to the external orifice of the cloaca genitalis.

In following out a series of sagittal sections of the proglottids, which are, of course, transverse to the direction of the cloaca genitalis, it will be seen that, as a rule, the cirrus sac becomes separate from the vagina in a position which is at first obliquely anterior to the vagina. This is the same on both sides of the body; but it is not invariably that the cirrus sac thus opens into the genital cloaca anteriorly of the vagina. I have seen one case (text-fig. 28, p. 208) in which the vagina lay anteriorly to the cirrus sac, and in this case an obliquity occurred in the relative positions of the two tubes, but the obliquity was in the reverse direction to that shown in the normal arrangement. The obliquity, that is the more dorsal or ventral inclination of the cirrus sac to the vagina, is already known to vary; thus, in *Moniezia* the position in relation to each other of the two tubes varies according as to whether they belong to the right or left side of the body, while in *Avitellina centripunctata* Dr. Gough has figured, in his paper already referred to†, an alternation of this kind in successive segments and on the same side of the body. There is, however, here no question of a reversal of an anterior to a posterior position such as I have found in *Otiditenia eupodotidis*.

In one case I found another remarkable variation. This was the complete absence of the proximal part of the vagina; into the cloaca genitalis opened only a cirrus sac. However, as the series of sections in which I observed this variation was traced further towards the middle line of the body, the median region of the vagina, which is of small calibre, came into view. In any case, the wide region of that tube which, in normal cases, opens into the cloaca genitalis was completely absent, save, indeed, for a few traces of its muscular longitudinal sheath.

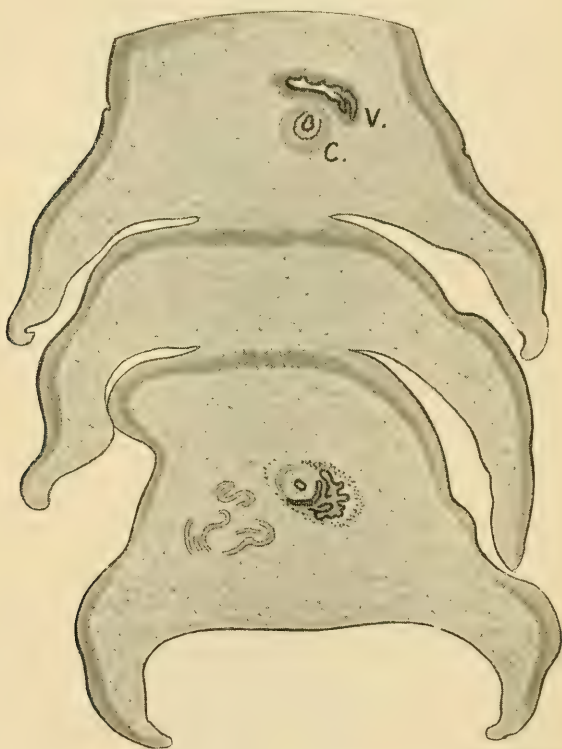
The *vagina* issues from the cloaca genitalis in an oblique position, as seen when the worm is studied in a series of sagittal sections, save, of course, for the exceptions mentioned above. It runs parallel with and later in close contact with the dense coil of

* "A Monograph of the Tapeworms of the Subfamily Avitellininae," Quart. Journ. Micr. Sci. vol. lvi. 1911, pl. xii, fig. 16, *at.*

† *Loc. cit.* pl. xiv. fig. 43.

the vas deferens on the ventral side. At first the vagina is wide, with a much plicated lining epithelium surrounded by a thick layer of muscles. It then suddenly becomes much narrower—these two regions of the vagina being thus analogous to the wider distal sac-like part of the cirrus and the narrow proximal part of the same. The narrow region of the vagina joins the wider region at an angle. Followed back the narrow part of the vagina dilates with moderate abruptness into the large receptaculum seminis, which commences at a point about on a level with the pore side of the large ventral water vascular vessel.

Text-fig. 28.



Sagittal section showing different position of cirrus (C.) and vagina (V.) in two segments of *Otiditenia eupodotidis*.

The *cirrus sac* among the Tetracotylea occurs in at least two types of structure. One, the most general, is typified, for example, by that seen in *Stilesia* and represented in a figure in Dr. Gough's paper upon that genus and *Aritellina*, and discussed in a footnote concerning the cloaca genitalis. The second type, which is certainly not so general, is seen in a genus *Anoplotenia*, the anatomy

of which I have lately given an account to this Society*. In the former type, as will be seen in Dr. Gough's paper referred to, the cirrus sac contains a narrow cirrus which is protrusible from the sac and is of pretty well the same dimensions, through the sac not being at all wider at its free extremity. In *Anoplotenia* the cirrus-apparatus is divided into two regions; there is distally a protrusible sac of much greater calibre than the slender cirrus which is continuous with it posteriorly. The protrusible sac appears to be an ingrowth into the cirrus sac of the cloaca genitalis. It is this kind of terminal male apparatus which we find in the tapeworm which forms the subject of the present communication to the Society. I have examined into its structure both by transverse and longitudinal sections, and have found that it presents certain differences from the cirrus sac of *Anoplotenia*. It has already been said, in describing the cloaca genitalis, that the end of the cirrus sac protrudes into that cavity; how far it can be protruded without any further temporary dislocation of its parts I do not know. It is evident, however, that, as with *Anoplotenia*, so in *Otiditenia*, there is a terminal section of this apparatus which can be protruded, though I have not met with specimens in which the protrusion is actually effected. Text-fig. 27 (p. 206) shows a longitudinal section through a cirrus sac that is seen in a transverse section of the proglottid containing it. It will be seen that the whole organ is of considerable size, though not so large proportionately as it is in *Anoplotenia*. It is, however, of much the same shape, being a slightly elongated sphere, though flask-shaped when fully retracted. The sperm-duct in this particular specimen approaches the cirrus sac from one side, and then sharply curves to enter it. The point of entry is at the extreme posterior end, *i. e.* that furthest removed from the orifice of the cirrus sac into the cloaca genitalis.

The sperm-duct is a good deal coiled within the cirrus sac and has clear slightly stained walls. It does not, however, become enlarged anywhere to form a vesicula seminalis. The transition between the sperm-duct and the cirrus is abrupt. The cirrus is not, however, of greater calibre, or at most of very slightly greater calibre, than the sperm-duct with which it is continuous. The abruptness of the transition lies in the fact that the walls of the cirrus are thick and very deeply stained and the lumen proportionately reduced. The cirrus is very much shorter than the section of the sperm-duct which lies within the cirrus sac; it is slightly coiled. The cirrus itself again terminates abruptly in a wider sac. As will be seen in text-figure 27, this latter sac is flask-shaped, and, in fact, broadly corresponds in outline with the entire cirrus sac. The wider part of the flask lies within the wider part of the cirrus sac and the narrower part in the neck of the latter.

The whole sac is composed of a deeply staining epithelium,

* P. Z. S. 1911, p. 1003.

which is quite continuous above with the lining of the genital cloaca and below with the epithelium of the cirrus sac. The epithelium appears to be quite the same throughout this whole tract. It is clear, in fact, that both the narrow cirrus and the flask-shaped pouch into which it opens form one structure possibly invaginated from the genital cloaca, which is quite distinct morphologically from the sperm-duct. The cirrus sac itself is also divisible into two regions when it is occupied by the fully retracted cirrus, as shown in text-figure 27. The almost spherical distal part leads through a narrower neck to the cloaca genitalis. The spherical bulb is covered externally by a thin layer of muscle-fibres. The interior of the sac is filled with a tissue like that seen in the cirrus sac of other tapeworms, for example, in *Anoplotenia*, where I have represented its principal characteristics*.

There are many nuclei belonging apparently to delicate muscular fibres and forming a padding tissue between the contained coils of the male efferent system. Running from the wall of the cirrus sac furthest from the pore are muscular slips which are attached to the nearest end of the wide sac into which the cirrus opens and are doubtless retractile in function. The narrower neck-part of the cirrus sac is tubular and has a much thicker coating of muscles, which are circular in direction. This layer is one with the thin muscular coat of the bulb-region of the cirrus sac. Between this thick muscular coating and the terminal part of the male efferent apparatus which lies within it is seen a delicate muscular layer with abundant interspersed nuclei like the packing tissue of the bulb of the cirrus sac. The fibres, however, have a definitely longitudinal direction, and would seem to be part of the retracting apparatus.

It has been mentioned that the cirrus sac projects into the cloaca genitalis. The surface which thus projects is covered on that part of it which faces the external pore by close *chevaux de frise* of minute conical spines, which are not implanted hooks such as often occur upon the cirrus in tapeworms, but rather appear to be outgrowths of the cuticular covering. They suggest to some extent a comparison with a group of fine setæ described by Fuhrmann† in the two species *Anomotenia penicillata* and *A. isacantha* in an apparently similar situation.

The vas deferens immediately on leaving the cirrus sac forms a dense coil filling up a good deal of space. The tube is here wider than the sperm-duct within the cirrus, and the nuclei of the cells which constitute its walls are very obvious; the cells themselves are rather clear. I could find no vesicula seminalis along the course of the sperm-duct.

The uterus of this worm, together with its contents—the ripe or ripening embryos—shows certain definite peculiarities. At its first appearance the uterus is sac-like and narrow, lying in front of the ovaries and testes but still not very near to the anterior

* P. Z. S. 1911, p. 1015, text-fig. 215.

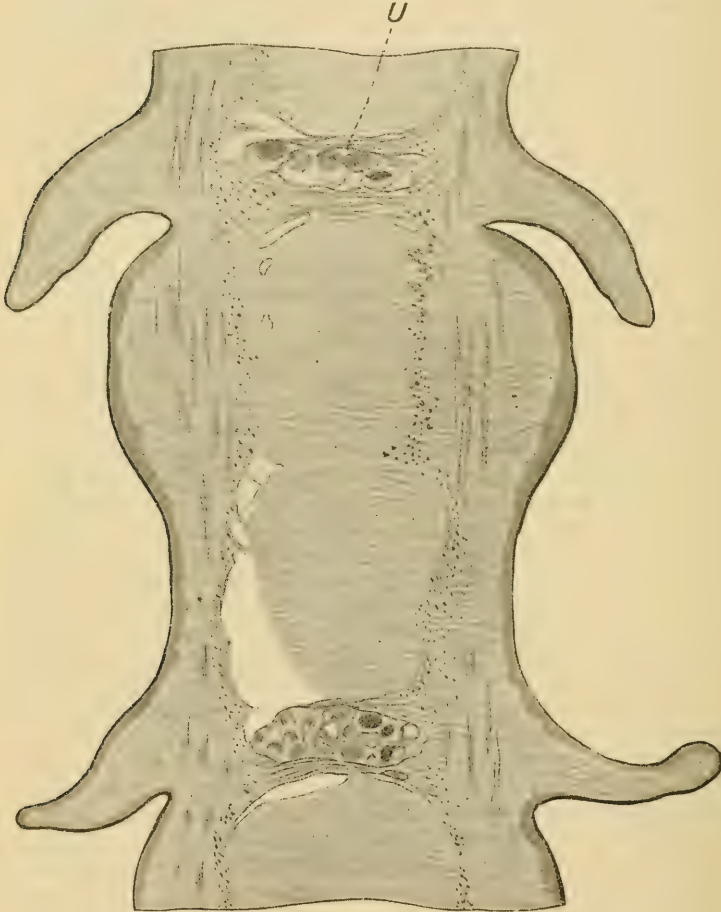
† Centralbl. f. Bakt. u. Parasit. xlv. 1908, p. 516.

border of the segment. In this stage, when it is empty of eggs, it forms a narrow transversely running tube. In transverse sections of a slightly older uterus, such as that which is represented in text-figure 24 (p. 201), the position of this part of the reproductive organs is seen to be remarkable. If such sections be examined from in front backwards, the uterus is the first part of the generative system to come into view; for, although posterior in position in its segment, the uterus lies in front of the ovaries and testes. In such sections it appears first of all dorsally as a narrow and transversely elongated sac, not lying in the medullary parenchyma, but lying within the internal and circular layer of muscles which delimit the medullary parenchyma from the cortical layer—the body-wall of the worm. The uterus, so to speak, splits this circular layer of muscles into two layers, fibres being recognisable both dorsally and ventrally of it. It has probably pushed its way into this situation; but located there the appearance given is most suggestive of a coelomic cavity lying between the body-wall and a central hypoblastic mass comparable to the reduced gut of certain simple Planarian worms (e. g. *Haplodiscus*). In such sections, moreover, the lumen of the uterus is seen to be not quite continuous from side to side of the body. Muscular fibres run across dorso-ventrally, which are of the nature of strands rather than septa. These are plainly shown in the accompanying illustration (text-fig. 29). Moreover, the epithelial lining of the uterus is quite alone in these transverse sections, its nuclei being very deeply stained.

This epithelial lining is continued over the strands of muscular tissue which partly divide up the cavity of the uterus. Although the uterus lies, as already said, below the dorsal parietes, there are here and there a few outpocketings of the cavity of the uterus, spherical in form, which push their way into the thickness of the dorsal parietes. Each of these contained only one or two groups of ovarian and vitelline cells, and in the case of one uterus I only found two of these small blind outgrowths. These transverse sections also show another fact in the constitution of the growing uterus, and that is its increased dorso-ventral diameter laterally, both on the pore side and on the opposite side. These dilated regions of the uterus were rather more liberally traversed by transverse strands than the rest of the cavity. The lateral widening of the uterus is also very plainly to be seen in horizontal sections, where it is visible even in rather younger proglottids than those just referred to. These longitudinal horizontal sections (see text-fig. 25, p. 202) also show very well the extension of the uterus on both sides of the body up to but not beyond the large ventral water vascular tubes. The cavity of the uterus is thus apt to be a little shorter from side to side than the space occupied by the testes. On the other hand, when viewed in a series of longitudinal sagittal sections, the uterus will be seen to have a greater dorso-ventral extension than the space occupied by the testes. In the three figures (text-figs. 24, 26, 29), which show

the gradual increase in importance of the uterus, it will be also observed that the total area occupied by the uterus and the rest of the generative organs diminishes in its proportion to the length of the segment in the older proglottids. It will also be noted that in the oldest proglottid figured (text-fig. 29) the testes are in course of disappearance.

Text-fig. 29.



Nearly mature proglottid of *Otiditania eupodotidis*, sagittal section.

U. Uterus.

In the ripe proglottids which are in course of being detached the condition of the eggs is remarkable in several ways. The

segments, as has been pointed out in considering the external characters of this worm, are enormously swollen so as to be almost globular in form, except for the frill-like posterior end of each proglottid, where it overlaps the one next in order behind it. It would be easily supposed that this tension of the proglottids is simply a matter of their being gorged with ripe eggs, such a dilatation of proglottids seen in other tapeworms being due to this cause. A microscopical examination, however, of such proglottids shows that this conjecture is wrong. By far the greater part of the interior of the proglottid contains no uterus or egg at all. Fully three-quarters of the area of the proglottid is quite empty of eggs, and the medullary substance only contains a few fragmentary remains of other parts of the sexual system—as I suppose, for I have not identified the vestiges in question with any certainty. Moreover, the dilatation is not due to the imbibition of fluid during the processes of preservation. It was as obvious in proglottids shed during the life of the bird as in those extracted from the gut after death.

I have examined such proglottids in both transverse and longitudinal sections. Both sets of sections prove that the ripe eggs (or rather embryos) are only present posteriorly in the segment. In one proglottid, which was completely cut into sections and mounted upon ten slides, no less than seven of these slides showed no embryos at all scattered through the parenchyma; in another proglottid, however, treated in the same way, embryos were found to lie in the more anterior region, though here also the most anterior part of the proglottid was devoid of eggs. In both of these specimens, however, and in several others which I have examined by means of sections, the ripe embryos or masses of embryos by no means occupied the whole of the parenchyma. There were large tracts of parenchyma quite uninvaded by the uterus or its remains.

The fact that the masses of eggs may in some cases lie rather more anteriorly in the segment than they are apt to do in less fully ripe proglottids is, as I think, in favour of Dr. Benham's view that a scattering of eggs takes place owing to a rupture of the uterus when the proglottids come apart*. The parenchyma in these ripe proglottids must now be considered, as its condition is doubtless related to the changes in the uterus that remain for description. In younger proglottids, such as those represented in text-figure 24, the parenchyma is firm in appearance, moderately stained by carmine, and with abundant very well-stained nuclei; these nuclei seem to have a prevalently dorso-ventral arrangement in lines. Calcareous corpuscles are abundant, especially towards the posterior region of the segment, where the generative organs are situated. In still older proglottids, which, however, are not yet detachable from the strobila, such as those represented in text-figure 29, the medullary parenchyma has taken on a

* Quart. Journ. Micr. Sci. vol. xliii., 1900.

different appearance. It is much more distinctly fibrous than in younger proglottids, as is plainly shown in the text-figure just referred to. The fibres run, on the whole, dorso-ventrally, and thus appear transverse in sagittal sections. The fibrous appearance of the parenchyma is particularly obvious where the fibres are frayed out, owing to the breakage of the section. In such sections the calcareous corpuscles are still quite plain, chiefly massed posteriorly in each segment. And, finally, in proglottids of this age the uterus retains the perfect regularity of its shape.

We may now revert to the ripe detached or quite easily detachable proglottids. The same fibrous appearance of the medullary parenchyma is plain; but, owing to the swelling of the whole proglottid, the fibres no longer run entirely transversely in a dorso-ventral direction, but tend, in places at least, to be more circular in the way in which they lie.

This is especially the case in the neighbourhood of the uterus. In these segments, however, we can no longer speak of a uterus like that of the earlier proglottids represented in the series of text-figures already dealt with (text-figs. 24-29). In the completely mature proglottids (text-fig. 30) under consideration the embryos are in partly or wholly detached masses of roughly spherical form consisting of more or fewer individual embryos. These spherical sacs, though of course vestiges of the uterus, seem to have no definite walls of their own, but to be bounded only by the fibrous tissue of the medullary parenchyma. There are comparatively few of them, and those so small as to contain only one embryo are very few. The spherical masses of embryos are encircled by the fibres of the medullary parenchyma in such a way as to produce the impression of a definite sheath, which is perhaps particularly obvious in the case of two such masses lying close together. This statement applies to the larger as well as the smaller masses of ova. There is not, however, any very great development of this sheath, the character of its fibres being quite like that of the surrounding parenchyma. Otherwise, we might speak of paruterine organs; and, in any case, it is to be pointed out that we may have here just the commencement of the formation of paruterine organs, which is carried much further, but along the same lines, in such a genus as *Thysanotenia* *. I take it, however, that there is nothing sufficiently definite to allow of the assertion that the present genus or species is to be characterised by the possession of paruterine organs. Before comparing the history of the development of the uterus in this species with that of other forms it will be necessary to follow the development of the contained eggs.

In the uterus, when in such a stage of development as is represented in text-figure 24, there are comparatively few eggs. In many sections the cavity of the uterus, which is not yet very spacious, is seen to be completely empty. When ova are present

* See Beddard, "On Two Genera of Tapeworms," P. Z. S. 1911, p. 994.

they are small and delicate-looking, and not accompanied by much interstitial matter. The uterus itself at this stage has not very marked epithelial walls. The appearance of the ova is, indeed, that of masses of the ovary transferred bodily to the uterus. Later on the lining epithelium of the uterus is quite obvious especially so far as concerns the nuclei of the same. In the uterus of this and some later stages the individual eggs (or embryos, as the case may be) are by no means always in close contact with each other. They are separated by and imbedded in a great deal of interstitial substance, which, as a rule, stains very faintly with carmine.

Text-fig. 30.



Mature proglottid of *Otiditania eupodotidis*, longitudinal section.

U. Chambers into which the uterus becomes divided.

It contains, however, a good many nuclei which do stain, and is thus evidently of a cellular nature. In the uteri of this

particular series of proglottids (shown in text-figure 25, p. 202) the accumulation of interstitial cells was chiefly in the uteral expansions close to the water vascular vessels. In these regions of the uterus the lumen was often entirely occluded by the densely packed contents. In the uterus of a later stage—that which is represented in text-figure 26—the embryos were firmly imbedded in the interstitial substance throughout the whole organ, so far as I could see. This substance appears much denser in the uterus of these older proglottids—so much so that cavities are left here and there from which an embryo has fallen out in the course of preparing the sections, which preserve exactly the spheroidal shape of the embryo. The interstitial matter also seems to take stains more readily at this stage, but exhibits no nuclei and no structure that I was able to unravel.

In the fully mature proglottids (see text-figure 30) this interstitial substance is still present, and the embryos are seen in the same way to be embedded in it, leaving cavities of exactly their shape when they chance to have fallen out. The interstitial substance, however, appears here to be rather laxer and is not so deeply stained. It is very possible that this matter lying between the eggs is a source of food-supply for the growing embryos. In *Avitellina centripunctata* Gough has described the fact that the eggs, after they have arrived in the uterus, “become surrounded by smaller cells derived from the walls of the uterus,” as has been pointed out by Fuhrmann in the case of *Stilesia sjöstedti*. These cells are figured by Gough* as lying between and apparently completely filling the interstices between the eggs. These cells have conspicuous nuclei and are held by Gough to perform a nutritive function with regard to the eggs.

This final disposition of the uterus, or perhaps rather of its contents, in *Otoiditenia eupodotidis* is not exactly like anything that is known to me at first hand or from the figures and descriptions of others. It is, however, suggestive of the figures that have been published of *Monopygidium* and even of *Davainea*. In his definitions of both of these genera (which are placed in separate families) Ransom† describes the fate of the uterus in almost exactly similar words: viz. “Uterus breaks down into (numerous) egg-capsules, each containing one or more (several) eggs.” This is a little misleading in that the sharply contoured and thick-walled capsules of certain species generally assigned to the genus *Davainea* are different from the figures given of *Monopygidium infundibulum* etc. The definition would, moreover, apply to *Otoiditenia*, in which, as I maintain, the conditions are really rather different from both.

In several species of *Monopygidium* the ripe eggs are scattered and imbedded singly in the medullary parenchyma, so far

* Gough, Quart. Journ. Micr. Sci. vol. lvi. pl. xiv. fig. 49.

† “The Taenioid Cestodes of North-American Birds,” Bull. U.S. Nat. Mus. no. 69, 1909.

suggesting the genus *Oochoristica* *. Of *M. rostellatum* Fuhrmann writes † that each egg is surrounded by "une parenchyme vacuaire qui forme des cellules hexagonales." This is represented in a figure which suggests a definite limiting membrane to each of these "cellules," and thus separating them from the general medullary parenchyma. In *M. cayennense*, *M. secundum*, and *M. macracanthum* the same author ‡ finds the same singly imbedded ripe ova. And this condition appears to characterise some other species of the genus *Monopylidium*. There is, however, another species of tapeworm recently described from *Gallinula chloropus* under the name of "*Tenia marchali*" by Mola §, which Fuhrmann || refers to the genus *Monopylidium*, in which the disposition of the ripe ova is rather different. Mola, in fact, figures the ova as not scattered singly through the parenchyma, but arranged in groups of one to six. Furthermore, he does not represent the parenchyma surrounding them as vacuolar (as does Fuhrmann in his species), but as distinctly fibrous. The state of affairs is therefore obviously much more like that of the species with which I am concerned in the present paper. Mola, however, does not show any tendency for the fibrous parenchyma to enwrap the bundles of eggs such as I have described above in *Otiditenia*. There is, furthermore, no suggestion given of an epithelial lining to the cavities which lodge the eggs in *M. marchali*.

Some important histological details are added by Clerc ¶ with reference to *Monopylidium infundibulum*.

In this species we have, as it would appear, an agreement with *M. marchali* in the fact that several ova are lodged together in one lacuniform cavity of the medullary parenchyma. But these cavities are not isolated; they form a complicated and irregular network of lacunae **. Later still, however, the individual ova become more completely separated the one from the other, and the typical (?) character of the genus *Monopylidium* is arrived at. It may also possibly be the case with *M. marchali*. I have, however, no reason to suppose that the metamorphosis of the uterus in my genus *Otiditenia* proceeds any further than is indicated in

* Cf., e.g., Beddard, P. Z. S. 1911, p. 633, text-fig. 150, e.

† Rev. Zool. Suisse, t. xvi., 1908.

‡ Centralbl. f. Bakt. Parasit. Bd. 45, 1907.

§ Bull. Ac. Belg. 1907, p. 886.

|| Die Cestoden der Vögel, Zool. Jahrb. 1908, Suppl.-Bd. x.

¶ Rev. Zool. Suisse, t. xi. 1903, p. 354. Ransom places this species in the genus *Choanotenia* on the grounds of his own observations as well as those of Cohn (Nova Acta Ac. Nat. Cur. Bd. lxxix., 1901), which seem to show that the uterus is persistent "and possesses an irregularly lobulated cavity incompletely subdivided by infoldings from the wall." This is, according to Ransom, a character of *Choanotenia*, and contrasts with the breaking up of the uterus in *Monopylidium*, which I have referred to above. I may point out, in support of Clerc, that Cohn's figure (*loc. cit.* pl. 32. fig. 47) may well indicate an incompletely mature uterus, since he represents in the same proglottid both ovaries and testes. In *Otiditenia*, at any rate, the ovaries and testes have disappeared when the uterus is fully mature. Cohn's figure may correspond to a stage figured in text-figure 30 of the present memoir.

** *Loc. cit.* vol. xi. figs. 73, 77, 85.

text-figure 30. Clerc also figures somewhat similar changes in the uterus of a species of *Dilepis** (not named), where the scattered ova actually penetrate the cortical parenchyma. This fact I have also observed in *Otiditænia*.

There are, therefore, clearly differences of importance between the ultimate fate of the uterus in the two genera—as I regard them—*Monopylidium* and *Otiditænia*. In the former the eggs are in most (? in all) species finally scattered through the parenchyma unaccompanied by any other cells such as occur with the ova in *Otiditænia*, in which genus the eggs are at the very end grouped into many more or less isolated but not well-marked capsules. There remains a comparison of the uterus of *Otiditænia* with that of *Davainea*. With regard to certain species of the latter there is no particular comparison possible. But Clerc has figured the egg-capsules of *Davainea frontina*†, which do seem to present certain similarities to the egg-capsules of *Otiditænia eupodotidis*. In the former worm the egg-capsules differ from those of such a species as *D. comitatus*‡ in that the individual eggs do not lie closely together within the capsule, but are more or less widely separated with a good deal of interstitial matter between them, which the author regards as a part of the medullary parenchyma which has undergone alteration. This and the enclosed eggs is surrounded by a definite layer of cells, which are not to be looked upon as a part of the persisting walls of the uterus, since in that case they would not enclose a portion of the medullary parenchyma. If this interpretation of the facts be correct, there is clearly no possible correspondence with the phenomena which I myself describe in the present paper. It seems to me, however, to be not impossible that the supposed altered parenchyma-cells which lie amongst the ova are really the equivalents of the similarly placed cells in my genus *Otiditænia*. Moreover, Ransom§ speaks of cells accompanying the scattered ova of *Davainea rhynchota*.

I am disposed, however, to think that there is another view to be taken of the egg-capsules of *Davainea frontina*, as figured by Clerc. From the account that he gives of them in the text and of the investigations of others on the same subject—to which we may add those of Leuckart||—it seems clear that the egg-capsules correspond to the paruterine organs of a genus recently described by myself¶ under the name of *Thysanotænia*, as I have already suggested. In this case we cannot agree with the statement of Ransom, in defining the subfamily Davaineinæ, that the “uterus breaks down into numerous egg-capsules.” For in *Thysanotænia* there is, I think, no doubt that the cases in which the eggs finally come to lie have nothing whatever to do with the uterus, and are,

* Clerc, *loc. cit.* pl. xi. figs. 75, 76.

† *Loc. cit.* pl. xi. fig. 80.

‡ Ransom, Bull. U.S. Nat. Mus. no. 69, p. 17, fig. 8, *cap*.

§ *Loc. cit.* p. 14.

|| Quoted in Bronn's ‘Thierreichs,’ p. 1445.

¶ P. Z. S. 1911, p. 1000.

in fact, paruterine organs. This is not the case with the sacs of eggs in *Otiditania*.

We may abstract from the foregoing account of the anatomy of this worm the following *résumé* of its structural characters:—

Length about 3 inches; greatest breadth 4 mm. Scolex with feebly developed rostellum with a marginal double circle of very numerous and small hooks. Suckers unarmed and rather large. Neck present and short. Proglottids broader than long, except at the extreme end of the body, where they become rather longer than broad. Completely mature proglottids almost spherical, except for the frill which overlaps the following proglottid. Two excretory tubes on each side, of which the ventral are very wide and the dorsal narrow; the two are at times parallel, but occasionally the dorsal tube is really somewhat dorsal in position. Ventral vessels joined by a wide cross-trunk at the posterior end of each proglottid. Generative pores alternate irregularly; the generative ducts pass between the dorsal and ventral trunks of the excretory system. The generative pores are not borne at the end of outgrowths of the proglottid. The testes lie at the extreme end of the proglottid and form a vertical wall of over 200 separate gonads, which, however, are included in a mass of medullary tissue rather different from the medullary parenchyma generally. The sperm-duct forms a large coil, and is also slightly coiled within the rather large cirrus sac. In the latter the actual cirrus is short and is connected with a wider (? eversible) tube also contained within the cirrus sac. The cloaca genitalis is deep. The ovary and vitelline gland lie in front of the testes. The vagina is furnished with a large receptaculum seminis. It opens into the cloaca genitalis behind and at right angles to the cirrus sac. The uterus lies in front of the ovary, and in mature segments the whole reproductive system is restricted to the posterior fifth or so of the proglottid. The uterus is a narrow transverse tube, wider at the two sides. Later it is broken up into several more or less spherical compartments. The eggs are imbedded, within the uterus, in a mass of cellular tissue whose origin is uncertain, and which later loses its cellular character.

We have now to consider whether the species described in the present communication can be referred to any known genus or whether it will be necessary to form a new genus for its reception. The abstract of the anatomical characters that has just been given shows that the worm is undoubtedly a member of the large family Hymenolepididæ or perhaps of the Davaineidæ. This conclusion need not be proved in detail. Furthermore, it is clear that the features which distinguish it, viz. the following assemblage of characters, necessitate its inclusion in one of the genera *Monopylidium*, *Choanotenia*, or *Anomotenia* of the Hymenolepididæ, or to a new genus altogether. These characters are:—Armed rostellum and unarmed suckers; large number of proglottids; alternate generative pores; absence of paruterine organs; testes behind ovaries; breaking up of uterus in ripe segments; and in

a number of points which we shall have to consider in fixing the position of this worm. It is true that the three genera mentioned are separated by somewhat slender characters, which is emphasized by the fact that *Choanotenia infundibulum* has been referred by Fuhrmann to the genus *Monopylidium*, and that the same author has left the position of *Choanotenia levigata* of Rudolphi in doubt.

All the three genera, however, seem to differ from that which forms the subject of the present paper by the strong muscular rostellum and by the relatively small number of the hooks, arranged in a single or a double crown. Moreover, the segments in representations of these genera are figured as considerably longer in proportion to their breadth than they are in *Otiditenia*. Finally (so far as concerns the more important point), the uterus appears to be a persistent and continuous sac in *Choanotenia* and *Anomotenia*, while the eggs in *Monopylidium* come to be scattered singly through the parenchyma. As I have endeavoured to show on a previous page *, the development of the uterus in *Otiditenia* is different. Nevertheless, I am disposed to place *Otiditenia* more nearly in the neighbourhood of these genera than in that of any others.

With regard to the Davaineidæ the present genus does undoubtedly show certain points of likeness to the genus *Davainea*, the definition of which genus is not, however, a matter of great ease. *Otiditenia* certainly lacks hooks upon the suckers, the existence of which in *Davainea* forms a part of its generic definition. But it must be remembered that *D. lateralis* from the mammal *Galeopithecus* has suckers without hooks. The breadth of the rostellum and its numerous hooks is a point of similarity to *Davainea*, in which genus the rostellum may be rather rudimentary (cf. Zschokke †). The principal reason, however, against assigning this worm from *Eupodotis kori* to the genus *Davainea* is the persistence of the uterus to the stage of the perfectly ripe proglottids, whereas in "the genus *Davainea* a definite functional uterus is not developed" (Ransom) ‡, and there are also paruterine organs.

The generic § characters of *Otiditænia* will be, as I believe, the following:—

Scolex with wide but rather rudimentary rostellum armed with over a hundred minute hooks arranged in two rows. Suckers unarmed. Neck present, not long. Proglottids for the most part wider than long, only as wide or slightly wider than long at the end of the body. Genital pores irregularly alternating. Detached proglottids very swollen, almost spherical. Water vascular vessels two pairs, ventral much the larger, nearly or quite lateral to each other; transverse trunks also wide. Genital organs not mature very early

* P. 210.

† Centralbl. f. Bakt. u. Parasit. 1895, p. 634.

‡ Bull. U.S. Nat. Mus. no. 69, 1909, p. 14.

§ I do not feel able to differentiate the specific characters.

in strobila. Testes numerous, at least 200 lying posteriorly in a thin vertical plate extending between water vascular vessels and even beyond them laterally, imbedded in interstitial tissue different from medullary parenchyma. No vesicula seminalis, sperm-duct with large coil; cirrus sac large, containing a looped part of sperm-duct, short cirrus, and an evaginable sac derived from cloaca genitalis. Ovaries and vitelline gland in front of testes. Uterus in front of ovaries, a narrow transverse sac with cavity partly divided by ingrowing trabecule. Later uterus converted into several spherical sacs. Eggs thin-walled, surrounded by nutritive (?) cells.

Hab. *Eupodotis kori*.

The most noteworthy characters of the genus, so far as the external characters go, appear to be the rather wide and rudimentary rostellum, which is, nevertheless, armed with very numerous though very minute hooks. The internal structure is remarkable for the restriction of the gonads to the extreme posterior part of each segment, and to the fact that the very numerous testes arranged only one deep are imbedded in a very different kind of medullary parenchyma, which is obvious to the eye on account of its feeble staining: by the peculiar form of the cirrus sac and the inclusion within it of an outgrowth of the genital cloaca, which is probably protrusible like the somewhat similar "penis" of *Anoplotaenia*: and by the fate of the uterus and the presence of interstitial cells lying among the eggs.

14. On the Milk-Dentition of the Ratel.

By R. LYDEKKER.

[Received September 30, 1911: Read November 21, 1911.]

(Text-figures 31 & 32.)

Many instances are known among extinct mammals in which the milk-dentition presents primitive features entirely lost in the teeth of the permanent series. In the equine *Merychippus*, for example, the cheek-teeth of the milk-series are of the short-crowned cementless type of *Ancytherium*, whereas those of the permanent set show the high-crowned and cemented type characteristic of the more specialised representatives of the family Equidæ*. So far, however, as I am aware, no such atavistic features have been recorded in the case of any existing mammals; and it is therefore of interest to bring to notice what appears to be a case of this nature.

In the ninth edition of the 'Encyclopædia Britannica,' Sir William Flower classed the Ratels (*Mellivora*) with the Badgers in the subfamily Melinæ; this classification was followed in Blanford's volume on Mammalia in the 'Fauna of British India'† and in Flower and Lydekker's 'Study of Mammals'‡.

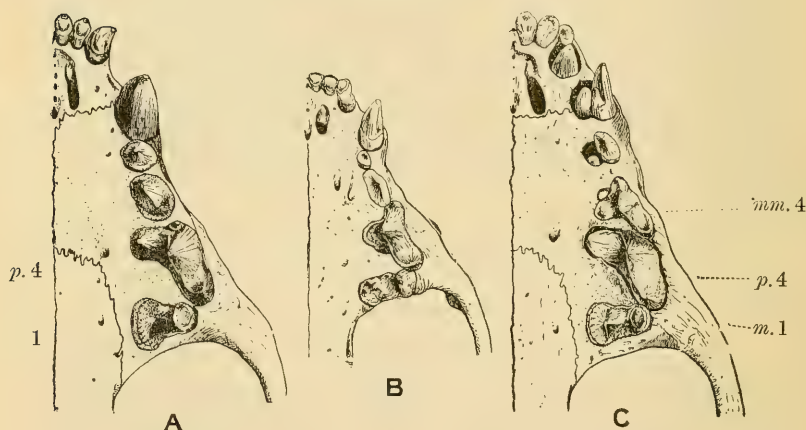
* See Lull, Amer. J. Science, vol. xxiii. p. 177, 1907.

† Page 175, 1888.

‡ Page 576, 1891.

When re-arranging, some fifteen years ago, the exhibition series of mammals in the British Museum I came, however, to the conclusion that this was incorrect; and in the label on the genus *Mellivora* I stated that although Ratels were generally classed with Badgers, it appeared, from their peculiar type of colouring and the form of the upper molar, that they ought to be placed next the Tayra and Grison (*Galictis*) in the subfamily Mustelinæ. This revised classification (which renders the definition of the last-named subfamily more concise) was followed in the revision of Sir William Flower's article "Carnivora," contributed by myself to the eleventh edition of the 'Encyclopædia Britannica,' and likewise in my account of the Mustelidæ in 'Harmsworth's Natural History'*. It has also been adopted in Max Weber's 'Säugetiere,' who probably follows Winge in this respect.

Text-fig. 31.

Left upper dentition of *Mellivora* and *Galictis*.A. Permanent teeth of *Mellivora*.B. " " *Galictis*.C. Milk-, and some of the permanent, teeth of *Mellivora*.

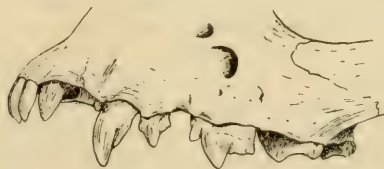
Thus matters stood till a few days ago, when I observed among a series of specimens sent to the British Museum by Miss Olive MacLeod from the Lake Chad district the skull of a Ratel in which the milk-dentition is just being replaced by the permanent set; the upper carnassial and molar being protruded, but the milk-carnassial being still retained, as are the milk-molars in advance of this tooth and the canines.

* Vol. i. p. 513. In revising the 8th ed., 1906, of the 'Guide to the Mammal-Galleries in the British Museum (Nat. Hist.),' I unfortunately allowed *Mellivora* to retain its old position (p. 45).

In the permanent upper dentition of Ratels the carnassial (*p. 4*), in common with that of nearly all other living Mustelines, has the inner tubercle placed close up to the front edge of the tooth, while the molar (*m. 1*) is characterised by the antero-posterior diameter of the inner half of the crown being greatly in excess of that of the outer half. In the milk-dentition, on the other hand, the carnassial (which in most Carnivora is a replica of the permanent one) has its inner tubercle placed near the middle of the blade; while, as I gather from another specimen, the inner half of the molar is much narrower than the outer, this tooth having, in fact, what may be called the typical carnivorous triangular form.

Now in both the foregoing respects the aforesaid milk-teeth correspond in general characters with their permanent representatives in *Galictis*; the upper carnassial of that genus being peculiar among existing Mustelines on account of having the inner tubercle placed near the middle of the blade. There are, of course, differences in regard to the details of these teeth, and also in respect to the orientation of the molar, when the milk-series of *Mellivora* is compared with the permanent set of *Galictis*; but the resemblance is such as to leave little doubt as to genetic affinity between the animals to which they respectively belong. And it would thus seem that the milk-teeth of the Ratel and the permanent ones of the Tayra represent a common primitive type, which has been superseded by a more advanced modification in the permanent teeth of the Ratel.

Text-fig. 32.



Outer side of left upper milk-dentition of *Mellivora*,
showing the bifid or bicuspid canine.

I find nothing very noticeable in regard to the hinder lower milk-teeth of the Ratel; but the upper canine has a distinctly bifid crown, as in certain Bats, and there are indications of a similar bifurcation in the corresponding lower tooth. Whether this is a primitive or a specialised feature, it is, in this case, difficult to say; it is almost certainly the former in Bats.

In referring to the teeth of *Galictis* as primitive in comparison with those of *Mellivora*, it should be mentioned that the comparison must be limited to those genera, as the permanent carnassial of Tertiary Mustelines, such as *Plesictis*, is of the *Mellivora-Mustela* type. That *Mellivora* is a more specialised

form than *Galictis* is evident, not only from the dental features already mentioned, but from the normal absence of the second lower molar (*m.* 2) and likewise by the shortness of the tail and the disappearance of the ear-conchs; both the latter features being, of course, adaptations to a burrowing life. In connection with the absence of the second lower molar, it is interesting to note that in one specimen in the British Museum (No. 9.7.19.1) this tooth is retained on the left side. It is very small, like the corresponding tooth of *Galictis*, and had come into use before the carnassial was fully protruded, so that it would have been shed early.

Although *Galictis* is now unknown north of Mexico, or thereabouts, it occurs fossil in the later Tertiaries of the United States; and this leads to the idea that *Galictis* and *Mellivora* are divergent members of a common stock which, like the Leopard (*Felis pardus* and *F. onca*) and Ocelot (*F. pardalis*, *F. tristis*, and *F. nebulosa*) groups, once inhabited a large area in Asia, whence it reached America by way of Bering Strait, and, having made its way into South America, died out in the north of the New World.

15. On a Further Collection of Mammals from Egypt and Sinai. By J. LEWIS BONHOTE, M.A., F.L.S., F.Z.S.

[Received October 24, 1911: Read February 6, 1912.]

The following is an account of a small collection of mammals which has been sent home during the past two years by Capt. Flower. The most notable specimens are the *Meriones crassus* and *Acomys russatus* from Sinai, the type locality of these species. Apart from their extreme rarity in collections, the acquisition of these animals has enabled me to identify definitely the *Meriones* of Lower Egypt with Pomel's *M. sellysi* and also to describe the form found in the Sudan as a new race. The specimens of *Acomys russatus* prove to be quite different in size and colour from those obtained near Cairo by Mr. Nicoll and myself, which latter are therefore described under the name *A. r. ægyptiacus* *.

I must express my indebtedness to Capt. Flower and Mr. Nicoll for their kindness in allowing me to work out the collection and more especially for bringing home some of the specimens alive, and thus enabling me to carry on some observations and experiments on which I shall hope to have something further to record in the future.

* The complete account of these two new subspecies appears here; but since the names and preliminary diagnoses were published in the 'Abstract,' No. 103, 1912, they are distinguished by being underlined.—EDITOR.

RHINOLOPHUS ACROTIS BRACHYGNATHUS K. Anders.

Rhinolophus acrotis brachygnathus K. Anders. Ann. Mag. N. II. ser. 7, vol. xv. p. 73 (1905); Bonh. P. Z. S. 1909, p. 788.

One specimen received from the Delta Barrage, 4th March, 1911.

CROCIDURA (CROC.) RELIGIOSA Geoffr.

Sorex religiosa Is. Geoffr. Mém. Mus, xv. p. 128, pl. iv. fig. 1 (1827).

Crocidura (Croc.) religiosa Is. Geoffr.; de Wint. in Anders. Zool. Egypt, Mamm. p. 168 (1902); Bonh. P. Z. S. 1909, p. 790.

Two examples, both males, of this minute species were brought in from Aburoash near Cairo. Their measurements are as follows:—

No. "A." Head and body 50 mm.; tail 37; hind foot 9; ear 7.

No. "B." Head and body 55 mm.; tail 40; hind foot 10; ear 8.

The skulls of both are in very good condition and show them to be quite adult. The skulls are identical in size, and measure: Greatest length 16 mm., greatest breadth 7; breadth across maxillæ 5; interorbital breadth 4; breadth of snout 2; tip of incisors to tip of large premolars 3·5.

CANIS ZERDA Zimm.

Canis zerda Zimm. Geogr. Gesch. ii. p. 247 (1780),

Vulpes zerda Zimm.; de Wint. in Anders. Zool. Egypt, Mamm. p. 233 (1902).

♂ near Muut, Oasis of Dakhel, 9th May, 1911,

This specimen was procured by Mr. Harding King, who has kindly presented it to the British Museum.

MUNGOS ALBICAUDA Cuv.

Herpestes albicauda G. Cuv. Règne Anim. ed. 2, i. p. 158 (1825); de Wint. in Anders. Zool. Egypt, Mamm. p. 193 (1902).

Capt. Flower brought back a very young example of this species from Abu Usher on the Blue Nile, taken on the 1st November, 1910.

GERBILLUS PYRAMIDUM Geoffr.

Gerbillus pyramidum Is. Geoffr. Dict. Class. H. N. vii. p. 321 (1825); F. Cuv. Trans. Zool. Soc. ii. p. 141, pl. xxv. figs. 6–9 (1838); de Wint. in Anders. Zool. Egypt, Mamm. p. 255 (1902); Bonh. P. Z. S. 1909, p. 791.

Three specimens of a large Gerbille said to have come from near Alexandria I have provisionally placed under this species. They are fully adult, but show a considerable range in size, the female being considerably smaller than the two males. From a comparison of these specimens with the series in the British Museum it seems probable that there are several forms of this species, but

the material at hand is not at present sufficient to admit of any definite conclusions being arrived at.

The measurements are as follows :—

♂. No. 358, J. L. B. : Hd. & b. 128 mm.; tail —; h.ft. 38; ear 17.

♂. No. 359 J. L. B. : Hd. & b. 126 mm.; tail 143; h.ft. 34; ear 17.

♀. No. 360, J. L. B. : Hd. & b. 116 mm.; tail 143; h.ft. 32; ear 17.

Skulls.	Greatest length.	Greatest breadth.	Least supra-orbital breadth.	Basal length.	Length of nasal.	Length of molar series.
♂. 358...	37 mm.	19	18	30	15	6
♂. 359...	38 „	20	8	30.5	15	6
♀. 360...	35 „	18.5	7	28	13.5	5

GERBILLUS GERBILLUS Oliv.

Dipus gerbillus Olivier, Bull. des Soc. Phil. Paris, ii. p. 121 (1801).

Gerbillus gerbillus Oliv.; de Wint in Anders. Zool. Egypt, Mamm. p. 252 (1902); Bonh. P. Z. S. 1909, p. 792.

The collection contains two more of this pretty and common Gerbille, one from the desert near Giza and the other from the Khargéh Oasis. In spite of its wide range this species is remarkably constant both in size and coloration.

MERIONES CRASSUS Sundev.

Meriones crassus Sundev. K. Vet.-Ak. Handl. p. 233, pl. ii. fig. 4, cranium (1843).

Gerbillus sellysii Pomel, C. R. Acad. Sci. xlii. p. 654 (1856).

Meriones shawi Rüpp.; de Wint. in Anders. Zool. Egypt, Mamm. p. 266 (1902) (partim).

I have lately received from Capt. Flower an example of *Meriones crassus* from Tor in Sinai. As this species was originally described from Sinai, this example represents the typical form of the species. It differs from that found in Lower Egypt in being slightly larger, with a more pointed snout and a much longer and stouter tail. The Egyptian specimens recorded by me in a former paper agree well with a series from Tripoli in the British Museum, which are practically topotypes of Pomel's species, and I have now no hesitation in referring them to this form. This I was unable to do before, owing to my having no typical *crassus* with which to compare them.

The form of *Meriones* found in the Sudan is much paler than that found in Lower Egypt, and I propose for it the name

MERIONES CRASSUS PALLIDUS.

Abstract P. Z. S. 1912, p. 3 (Feb. 13).

Meriones crassus sellysii Pomel, Bonh. P. Z. S. 1909, p. 793 (partim).

: Very similar to *M. crassus sellysii*, but much paler, and the

snout is, in life, rather more pointed, though this character is not obvious in the skull. In size they are a trifle larger and with a rather shorter tail.

The skull differs from that of *M. c. sellysii* in having a rather longer and narrower appearance. This is chiefly due to the slightly greater length of the auditory bullæ, which also project further behind from the base of the skull, and the skull itself is slightly narrower at its posterior margin.

Measurements of the type (in the flesh).—Head and body 127 mm.; tail 110; hind foot 28; ear 17.

Skull of type—Greatest length 39 mm., basal length 34, greatest breadth 23; palatal length 17; diastema 10; length of bullæ 16·5; length of molar series 5·5.

Type. Coll. J. L. B. No. 313. ♂. Atbara, Sudan. Collected by Capt. S. S. Flower.

The genus *Meriones* is one which offers great difficulties to the systematic worker, as the different forms resemble each other very closely and have at various times been burdened with many names and but imperfect descriptions.

The forms dealt with at present are, however, fairly distinct; the larger size and long and stout tail easily distinguish the typical *crassus*. *M. c. sellysii* (Tripoli and L. Egypt) is smaller, with a less pointed snout, rather paler in colour, and with longer and more conspicuous black tips to the hairs of the back. *M. c. pallidus* (Sudan) resembles *M. c. sellysii*, except in its much paler coloration. In life, however, the Sudan form has a more pointed snout, approaching in this character true *crassus*. From a comparison of the measurements below it will be seen that it is also slightly larger.

	Head and body.	Tail.	Hind foot.	Ear.
<i>M. crassus</i> , 1 example ♀	139 mm.	148	33·5	18
<i>M. c. sellysii</i> , av. 4 examples	126·5 „	120	29	17·5
<i>M. c. pallidus</i> , „ 4 „	131 „	112·5	31	18·2
<i>M. shawi melanurus</i> , 1 ex. ♀	139 „	135	32	17

In order to prevent any misunderstanding in the future, I may mention that these measurements and other particulars are all taken from wild specimens and do not in any way refer to a large series of these animals that I have bred in confinement.

MERIONES SHAWI MELANURUS Rüpp.

Meriones shawi Rozet, Voy. rég. d'Alger, p. 243 (sine descr.) (1833); Cuvier, Leçons d'Anat. Comp. iv. 2nd ed. 2nd part, p. 456 (1835); Duvernoy, Mém. Soc. Strasb. iii. p. 22, pls. 1 et 2 (1842).

Meriones melanurus Rüpp. Mus. Senck. iii. p. 95, pl. 7. fig. 3 (1845).

a. ♀ ad. Near Alexandria, Egypt.

This species, which is the one figured by Dr. Anderson, is easily

distinguished from the foregoing, as it is a larger and stouter animal, more closely approaching *Psammomys* in general build. In colour it is darker than *M. crassus*, the dark tips to the hairs being longer and much more conspicuous, especially on the tail.

The skull is more stoutly built and slightly longer, the extra length being almost entirely due to the longer molar series.

The teeth themselves, except in size, resemble those of *M. crassus*.

The most obvious skull-difference, however, is to be found in the auditory bullæ, which are much smaller and do not extend beyond the back of the skull.

The measurements of this specimen have been given under the preceding species to facilitate comparison.

The skull-measurements are as follows:—Greatest length 40 mm., basal length 35, greatest breadth 23; palatal length 19; diastema 11; length of bullæ 15; length of molar series 6.

PSAMMOMYS OBESUS Cretzschm.

Psammomys obesus Cretzschmar, Rüpp. Atlas, p. 58, pl. 22 (1828); de Wint., Anders. Zool. Egypt, Mamm. p. 274 (1902); Bonh. P. Z. S. 1909, p. 793.

Three specimens of the typical form from Maryût, L. Egypt.

MUS RATTUS TECTORUM Savi.

Mus tectorum Savi, Nov. Giorn. Pisa, Feb. 1825.

Mus rattus Linn.; de Wint., Anders. Zool. Egypt, Mamm. p. 274 (1902); Bonh. P. Z. S. 1909, p. 793; id. ibid. 1910, pp. 638, 651.

Mr. Nicoll shot an example of this form some distance up a tree. I have been trying to obtain evidence as to which of the two forms of *Mus rattus* climbs trees or whether both do it. This is the first *definite* evidence that *tectorum* is the climber, although there is a certain amount of indirect evidence on that point (see P. Z. S. 1910, p. 655). The question which requires settling is, does *M. r. alexandrinus* usually climb trees? On this point there is no evidence, direct or indirect. In confinement both forms climb with equal facility.

MUS MUSCULUS GENTILIS Brants.

Mus gentilis Brants, Muizen, p. 126 (1827).

Mus musculus Linn.; de Wint., Anders. Zool. Egypt, Mamm. p. 277 (1902); Bonh. P. Z. S. 1909, p. 794.

Two examples of this race of House-mouse, in which the hairs of the under parts are white to their bases, were brought back by Capt. Flower from Khartoum in the autumn of 1910.

MUS MUSCULUS, albino var.

Mr. Nicoll received from his correspondent Signor A. J. Balboni

in the Wadi Natron two examples of white mice, with the note that they were quite common in the Salt Company's buildings. These are apparently ordinary albino mice, similar to those which are domesticated throughout Europe. There is, however, no evidence to show whether these arose "spontaneously" or were imported by some previous occupant of the buildings and then escaped. I have asked Mr. Nicoll to try to procure further information on this point and also as to whether normal-coloured and piebald individuals are also found.

ACOMYS RUSSATUS Wagner.

Acomys russatus Wagner, Abh. Akad. München, iii. p. 195, pl. 3. fig. 2 (1840); Tristram, Fauna Palestine, p. 11, pl. 3. fig. 1 (1884).

I have received a pair of these rare mice alive from Sinai, the typical locality. This pair, which I received on May 3rd, gave birth on the 10th to three young. These were born, as in the case of *A. cahirinus**, in a very forward state of development, being very large and covered with hair and spines; they grew very rapidly and were about half grown and well able to fend for themselves when a fortnight old. They differ strikingly in coloration from the adults, being of a uniform pale grey throughout; when three weeks old the new adult coat of a lighter tint became visible on the under parts, and a week later the first trace of the yellow colour of the upper parts began to show on the shoulders; this coat gradually spread backwards towards the tail in a broad stripe along the centre of the back, the adult dress being finally completed along the flanks at the age of six weeks, by which time they were full-grown. I have been unable to note the exact period of gestation, but it is, I fancy, slightly longer than in the case of *A. cahirinus*.

This species is of a deep reddish brown on the back, each spine having a darker apex; the head is greyer and the under parts are greyish white, there being no sharp line of demarcation between the colours of the upper and under parts, as is the case in all other species of this genus, except *A. cahirinus*. The tail is short, being only about two-thirds the length of the head and body, and appears almost black, although it is sparsely covered with minute whitish hairs.

In my previous paper† I referred a specimen of an *Acomys* taken just outside Cairo to *A. cahirinus*. Since then I have received a second example obtained by Mr. Nicoll in the Wadi Hof near Helouan, and through the kindness of Capt. Flower I have also received, as noted above, a pair of *Acomys russatus* alive from Sinai.

This being the typical locality of *A. russatus*, the live ones are topotypes, and they differ in several particulars from those found

* P. Z. S. 1911, p. 5.

† P. Z. S. 1909, p. 795.

in Egypt; the Egyptian form is therefore undescribed, and I propose for it the name

ACOMYS RUSSATUS ÆGYPTIACUS.

Abstract P. Z. S. 1912, p. 3 (Feb. 13).

Very similar to *Acomys russatus* Wagner, but smaller and much brighter and yellower in coloration. Character of the fur spiny throughout, except on the vent, shoulders, thighs, and side of the face. General colour above bright orange-brown, each spine with a minute tip of dark brown, which, however, is not sufficient to affect the general coloration. Hands, feet, and under parts greyish white, shading into the colour of the upper parts with no definite line of demarcation. Skin of ears and tail black, thickly covered in the case of the ears with greyish hair on both surfaces and in the case of the tail with short greyish spines. There is a small but conspicuous white spot below the eye.

The skull, which I described in my previous paper, has the snout rather shorter and broader than its allies and the bullæ considerably larger, while the teeth and length of the molar series are also of greater dimensions.

Measurements of type (in flesh).—Head and body 91 mm.; tail, damaged; hind foot 17; ear 16.

Skull.—Greatest length 27 mm., basal length 22, greatest breadth 13; palatal length 12·5; diastema 7·5; length of molar series 5; length of nasals 10.

Type. Coll. J. L. B. No. 306. ♂ adult. Wadi Hof, near Helouan. Collected by Mr. M. J. Nicoll, 29th October, 1909.

As compared with the true *A. russatus* this form would appear to be rather smaller and much brighter in coloration.

Measurements of an adult ♀ (in the flesh) of the typical race are: Head and body 115 mm.; hind foot 19; ear 18; it is therefore considerably larger than the Egyptian form. Except in size the skulls of *A. r. ægyptiacus* and the typical form are very similar.

The skull-measurements of *A. russatus*, typical race, are as follows:—Greatest length 30 mm., basal length 25, greatest breadth 15; palatal length 13·5; diastema 8; length of molar series 5·5; length of nasals 11·5.

SPALAX ÆGYPTIACUS Nehring.

Spalax typhus Pall., Anders. P. Z. S. 1892, p. 472.

Spalax ægyptiacus Nehring, SB. Gesellsch. naturf. Fr. Berlin, 1897, p. 180; id. *ibid.* 1900, p. 210; de Wint. in Anders. Zool. Egypt, Mamm. p. 168 (1902).

Two examples of this scarce and little-known Rodent were received from Maryût in the Delta.

LEPUS SINAITICUS Hemp. et Ehr.

Lepus sinaiticus Hemp. et Ehr. Symb. Phys., Mamm. ii. pl. 14.

fig. 1 (1830); de Wint. in Anders. Zool. Egypt, Mamm. p. 322 (1902).

♂. Sinai, 23rd May, 1911.

This specimen, which was brought back from Sinai, through the courtesy of Capt. J. Falconer Bey, is in very rough and worn pelage. It has not yet been recorded from Egypt, and may be distinguished from *L. aegyptius* by its paler coloration and shorter hind foot.

PROCAVIA sp. ?

A fine example of a Hyrax, which was taken near Ras Gurdi, between Keneh and the Red Sea, was recently sent home. As the locality is very near the spot where the examples of *P. burtoni* mentioned in my previous paper came from, it is more than likely that this specimen also belongs to that species. It shows, however, the yellow spot round the dorsal gland which is absent in other examples of *P. burtoni*, although present in *P. ruficeps*; on the other hand, the head does not show the rufous tinge characteristic of the last-mentioned form. Unfortunately the skull, which would have settled the difficulty, was accidentally lost. I incline to the belief, however, that it is *P. burtoni*, and if so it must be borne in mind that when in worn pelage this species *may* show the yellow dorsal spot. The teeth, however, would form a definite distinguishing character.

EXHIBITIONS AND NOTICES.

February 6, 1912.

E. G. B. MEADE-WALDO, Esq., Vice-President,
in the Chair.

THE SECRETARY read the following report on the additions made to the Society's Menagerie during the months of November and December, 1911, and January, 1912:—

NOVEMBER.

The registered additions to the Society's Menagerie during the month of November were 247 in number. Of these, 119 were acquired by presentation, 28 by purchase, 17 were received on deposit, 77 in exchange, and 6 were born in the Gardens.

The total number of departures during the month, by death and removals, was 261.

Amongst the additions special attention may be called to the following:—

1 Spotted Hyæna (*Hyæna crocuta*) and 1 Crowned Duiker (*Cephalophus coronatus*), from the Gold Coast, presented by Capt. C. H. Armitage, D.S.O., on November 6th.

1 Kashmirian Deer (*Cervus kashmeerianus*), from Kashmir, presented by H.G. the Duke of Bedford, K.G., President of the Society, on November 16th.

4 Reindeer (*Rangifer tarandus*), from Lapland, presented by the European Construction Co., on November 11th.

1 Tasmanian Wolf (*Thylacinus cynocephalus*), 5 Tasmanian Devils (*Sarcophilus satanicus*), and 2 Bennett's Wallabies (*Macropus bennetti*), from Tasmania, purchased on November 21st.

A collection of small rodents containing several species new to the Collection, and specimens of two species of Elephant-Shrews, both new to the Collection, from Bechuanaland, presented by Capt. H. A. P. Littledale, F.Z.S., on November 18th.

A Hunting-Dog (*Lycabn pictus somalicus*), from Somaliland, presented by Lieut. H. C. Dobbs, I.A., on November 21st.

A Bengal Fox (*Vulpes bengalensis*), from Bombay, presented by Alfred W. Hanckel, Esq., on November 10th.

A Long-eared Fox (*Otocyon megalotis*), from South Africa, forwarded by Dr. Louis Péringuey, C.M.Z.S., on November 18th.

2 Ruffed Lorieets (*Calliptilus solitarius*), from the Fiji Islands, new to the Collection, received on deposit on November 6th.

1 Aztec Jay (*Cyanocitta stelleri azteca*), from Mexico, and 2 Swamp-Sparrows (*Melospiza georgiana*), from North America, new to the Collection, received in exchange on November 8th.

2 Cuban Banded Woodpeckers (*Nesocoeleus fernandinae*), 1 Cuban Green Woodpecker (*Xiphidiopicus percussus*), and 4 Black-throated Crested Quails (*Euphychorptyx nigrigularis*), the latter from Central America, all new to the Collection, received in exchange on November 22nd.

DECEMBER.

The registered additions to the Society's Ménagerie during the month of December were 88 in number. Of these, 38 were acquired by presentation, 2 by purchase, 31 were received on deposit, 14 in exchange, and 3 were born in the Gardens.

The total number of departures during the month, by death and removals, was 211.

Amongst the additions special attention may be called to the following:—

1 Wild Cat (*Felis sylvestris*), from Inverness-shire, purchased on December 20th.

4 Arctic Foxes (*Vulpes lagopus*), from Spitzbergen, deposited on December 11th.

6 Green White-eyes (*Zosterops virens*), from South Africa, new to the Collection, received in exchange on December 16th.

1 Concave-casqued Hornbill (*Dichoceros bicornis*), from India, received in exchange on December 1st.

4 Chinese Alligators (*Alligator sinensis*), from China, deposited on December 18th.

1 Kirtland's Tree-Snake (*Thelotornis kirtlandi*), 1 Green Tree-Snake (*Dendraspis viridis*), from Dunkwa, presented by Dr. H. G. F. Spurrell, F.Z.S., on December 16th.

JANUARY.

The registered additions to the Society's Menagerie during the month of January were 88 in number. Of these, 50 were acquired by presentation, 3 by purchase, 11 were received on deposit, 5 in exchange, and 19 were born in the Gardens.

The total number of departures during the month, by death and removals, was 267.

Amongst the additions special attention may be called to the following :—

1 White-throated Capuchin (*Cebus hypoleucus*), from Panama, presented by Francis Wright, Esq., on January 31st.

2 Grand Galagos (*Galago crassicaudata*), and 1 Blotched Genet (*Genetta tigrina*), from the Transvaal, presented by Commander F. J. Moseley, on January 20th.

1 African Red-winged Starling (*Amydrus morio*), from S. Africa, new to the Collection, received in exchange on January 3rd.

1 Yellow-rumped Hangnest (*Pseudoleistes guirahuro*), from S. America, new to the Collection, presented by Miss V. Bromwich on January 22nd.

1 Yellow-lored Amazon (*Chrysotis xantholora*), from Paraguay, purchased on January 4th.

2 Blue-rumped Parrakeets (*Psittinus incertus*), from Malacca, received in exchange on January 3rd.

1 Abyssinian Love-bird (*Agapornis taranta*), new to the Collection, deposited on January 3rd.

1 Calabar Snake (*Calabaria reinhardti*), from W. Africa, new to the Collection, presented by S. H. Carnelley, Esq., on January 16th.

1 Schott's Snake (*Philodryas schotti*), from S. America, new to the Collection, received in exchange on January 18th.

A Colour Phase of the Polecat.

Mr. E. G. B. MEADE-WALDO, V.P.Z.S., exhibited a mounted specimen of a pale fulvous variety of the common wild Polecat (*Putorius putorius*), belonging to the Rev. D. Edmondson Owen, of Llandovery, S. Wales. The animal resembled in colour a well-known variety of the Badger, and was interesting because the Polecats in that particular district were frequently of this peculiar variety and had been well known locally for years.

Retarded Development in a Red Kangaroo.

THE SECRETARY communicated the following account of retarded development of the foetus in a Red Kangaroo, by Mr. ROBERT D. CARSON, C.M.Z.S. :—

A female Red Kangaroo (*Macropus rufus*) was received at the Philadelphia Zoological Garden, June 5, 1908. On December 15, 1908, the movement indicating a young one was observed in her marsupium; this young one became ♂ No. 21 on our records.

The father of this young one came August 6, 1908, and died October 28, 1908, seven weeks before ♂ No. 21 was noticed.

♂ 21 ceased going into his mother's pouch June 6, 1909, and stopped nursing about November 7, 1909.

On September 25, 1909, movement was again observed in the female's pouch and proved to be what became on our records ♂ No. 22.

As the father of the first one, ♂ No. 21, had been dead 11 months less 3 days and no other male had been with this female nor in the collection, except the older young one, which was still nursing and very small and immature when the second young one was first observed, the question is which animal was the father of the last born?

It does not appear possible that it was the older young male, as that must have been at least two months younger still when conception took place.

As there is no possibility of this female having been impregnated by any other male of her own or any other species, the only explanation appears to be that of retarded development of one egg or foetus.

In Darwin's 'Descent of Man,' under "Manner of Development" it is stated that "In various Mammals the uterus graduates from a double organ with two distinct orifices and two passages as in the marsupials into a single organ . . . as in the higher apes and man"; also 27 lines further on are six lines indicating possible functional development in the double uterus.

Did the adult male impregnate this female twice, one egg

developing in one half of the uterus while the other lay dormant or developed more slowly in the other half during the months necessary to account for the delay in birth?

Male No. 22 is still living, and is a typical *Macropus rufus*.

PAPERS.

16. Report on the Deaths which occurred in the Zoological Gardens during 1911. By H. G. PLIMMER, F.R.S., F.Z.S., Pathologist to the Society.

[Received February 3, 1912: Read February 6, 1912.]

On January 1st, 1911, the number of animals in the Zoological Gardens was 3184, and during the year 3493 animals were admitted, making a total of 6677 for the year.

The number of deaths during the year has been 1647—that is, a death-rate of 24·6 per cent.; but if from the above total we deduct 801 animals which did not live for six months after their arrival in the Gardens—that is, the time at which we find they have either got over their journeys, or died from any disease they brought with them, or have got fairly used to their new environment—the percentage of deaths is reduced to 12·6, which is considerably less than those of the past three years.

The following figures will show the general results of the last four years:—

	1908.	1909.	1910.	1911.
Total number of animals	5608	5303	5540	6677
Total deaths	1737	1492	1554	1647
Percentage of total deaths	31	28	28	24·6
Percentage of deaths, excluding those which occurred in animals which had <i>not</i> been six months in the Gardens	17	17·8	16·4	12·6

In any case the figures for 1911 show a considerable improvement on those of the last three years, and if the relative numbers be borne in mind, the improvement is much more marked.

The total deaths are divided as follows: Mammals 359, Birds 849, Reptiles 439.

The following tables show the facts ascertained in outline. Table I. sets forth the actual causes of death in each of the three groups specified. Under Reptiles are included Amphibia.

TABLE I.—Analysis of the Causes of Death.

Diseases.	Mammals.	Birds.	Reptiles.	Reference to Notes following.
1. Microbic or Parasitic Diseases.				
Tuberculosis	18	106	23	1
Mycosis	3	103	...	2
Pneumonia	48	81	93	3
Septicæmia	3	...	...	4
Abscess	1	1	1	...
Pericarditis	8	3	1	5
Peritonitis	3	...	...	...
Stomatitis .....	...	...	4	...
Pleuritis	2	...	...	...
Distomiasis	1	...	...	6
Hydatids	3	...	...	...
Worms .....	...	3	7	7
Hæmogregarines .....	...	...	6	...
Malaria .....	...	1	...	...
Cystitis	1	...	...	...
2. Diseases of Respiratory Organs.				
Broncho-pneumonia	41	...	...	8
Congestion of lungs	27	106	23	9
Atelectasis	2	...	...	...
Bronchitis	4	...	...	...
3. Diseases of the Heart.				
Fatty degeneration	2	4	2	...
4. Diseases of the Liver.				
Fatty degeneration	3	22	5	...
Hepatitis	2	5	...	...
Cirrhosis	1	...	...	...
Angioma	1	1	...	...
5. Diseases of Alimentary Tract.				
Gastritis .....	...	1	1	...
Gastric ulceration	8	...	1	...
Gastro-enteritis	15	6	16	10
Enteritis	39	214	20	11
Intussusception	2	...	1	...
Intestinal obstruction	1	1	1	...
6. Diseases of Urinary Organs.				
Nephritis	48	33	8	...
Fibrosis of kidneys	3	8	...	...
Stone	2	...	...	12
Inflammation of oviduct .....	...	2	...	...
7. Various.				
Carcinoma	2	...	1	13
Sarcoma .....	...	2	...	14
Senile Decay	2	...	...	...
Anæmia without ascertained cause	1	...	3	...
Injuries discovered <i>post-mortem</i>	6	5	2	...

Besides those tabulated above,

120 animals were killed by order or by companions,

151 „ died of malnutrition and starvation,

1 animal was not examined,

138 animals were too stale for detailed examination,

these completing the total.

In Table I. the classification is made into those diseases which actually caused the death of the animals, but in a large number of the Mammals, Birds, and Reptiles other lesions were present which helped towards the fatal issue, and these are classified in Table II. If this Table be taken together with Table I. a much more accurate estimate of the amount of disease in the Gardens will be arrived at.

TABLE II.—Other Diseases found in the animals tabulated in Table I.

Diseases.	Mammals.	Birds.	Reptiles.	Reference to Notes following.
Tuberculosis	10	7	...	15
Mycosis .....	...	7	...
Pneumonia	5	2	4	
Empyema	1	...	...
Pericarditis	5	4	...	
Peritonitis	3	...	...
Pleuritis	1	...	...
Pancreatitis .....	...	4	...
Malaria .....	...	28	2
Filariae	1	30	1	
Worms	12	13	17	
Hæmogregarines .....	...	...	22
Trypanosomes .....	...	1	1
Stomatitis	1	...	4	
Abscess	5	2	1	
Splenic infarcts	5	16
Cystitis	3	...	...
Bronchitis	1	...	...
Broncho-pneumonia	6	...	1	
Congestion of lungs	20	58	9	
Edema of lungs	4	39	25	
Emphysema	2	...	...
Hydrothorax	4	...	...
Dilated heart	21	9	1	
Atheroma	3	3	...	
Fatty liver	13	57	23	
Hepatitis .....	...	11	...
Gastritis	3	...	...
Gastric ulceration	23	2	3	
Enteritis	21	43	18	
Intussusception	8	1	1	
Nephritis	20	15	2	
Fibrosis of kidneys	4	16	3	
Cystic kidneys	1	...	...
Ascites	4	4	11	
Tumours	3	...	...
Myelitis	2	...	...
Rickets	24	5	...	
Fat embolism .....	...	...	1

TABLE III.—Shows the Distribution of Diseases causing Death amongst the principal Orders of Mammals.

Diseases.	Primates.	Carnivora.	Rodentia.	Ungulata.	Edentata.	Marsupialia.
Tuberculosis.....	7	6	2	2	...	1
Mycosis.....	...	...	...	...	...	3
Pneumonia.....	14	17	7	7	2	1
Septicæmia.....	1	2	...	...	...	...
Abscess.....	...	...	...	1	...	...
Pericarditis.....	2	4	1	...	...	1
Peritonitis.....	...	...	...	3	...	...
Pleuritis.....	1	1	...	...	...	...
Distomiasis.....	...	...	...	1	...	...
Hydatids.....	2	...	...	1	...	...
Cystitis.....	...	...	1	...	...	...
Broncho-pneumonia.....	17	10	7	5	2	...
Congestion of lungs.....	14	2	8	3	...	...
Atelectasis.....	...	1	...	1	...	...
Bronchitis.....	3	...	...	...	1	...
Fatty heart.....	1	1	...	...	...	...
Fatty liver.....	1	1	1	...	...	...
Hepatitis.....	...	...	2	...	...	...
Cirrhosis of liver.....	...	...	...	1	...	...
Angioma of liver.....	1	...	...	...	...	...
Gastric ulceration.....	3	4	...	...	...	1
Gastro-enteritis.....	3	7	3	1	...	1
Enteritis.....	19	9	4	4	1	2
Intussusception.....	1	...	1	...	...	...
Intestinal obstruction.....	...	1	...	...	...	...
Nephritis.....	12	14	10	7	1	4
Fibrosis of kidneys.....	...	2	1	...	...	...
Stone.....	...	1	...	...	...	1
Carcinoma.....	...	...	...	...	...	2
Senile decay.....	...	...	...	2	...	...
Anæmia.....	...	1	...	...	...	...
Injuries.....	...	2	...	1	...	3

*Notes on the foregoing Tables.**I. General.*

The following calculations will show better what the figures on page 235 mean. On the average of the past three years, *taking into consideration the different numbers of animals in each year*, the figures for 1911 should have been, roughly:—

Total deaths.....	2020
Percentage of total deaths.....	36
Ditto, excluding those animals which had not been six months in the Gardens.....	20

So that the improvement is really much greater than appears from the mere figure-statement.

The principal percentage improvement is in the Mammals, which come out for 1911, as compared with the three previous years, roughly as 22 is to 31.

The following table shows the deaths amongst the Mammals from the numerically most important diseases for the four years 1908-1911 :—

	1908.	1909.	1910.	1911.
<i>Total number of animals ...</i>	5608	5303	5540	6677
Tuberculosis	59	17	18	18
Pneumonia	47	43	31	48
Septicæmia	12	15	7	3
Broncho-pneumonia	44	51	50	41
Congestion of lungs	29	38	41	27
Gastro-enteritis	23	11	19	15
Enteritis.....	72	46	32	39
Peritonitis	15	4	6	3

The Birds do not show any percentage reduction of mortality ; and the great relative mortality of birds in the Gardens is due, in my opinion, largely to the overcrowding of many of the aviaries.

The Reptiles show the largest percentage mortality ; this is, in my opinion, partly due to the fact that so many of them arrive heavily laden with parasites of all sorts—some having as many as four different species—and partly to the present unphysiological method of feeding them.

II. *Special.*

1. The percentage of tubercle has fallen to 7·8 per cent. in the Mammals, 13·3 per cent. in the Birds, and is 5·4 per cent. in the Reptiles, which is relatively less than last year all round.

In 6 Mammals and 41 birds it was a general tuberculosis. In a Lion it was of the human type with cavitation of lungs, and in 7 Birds it was of bovine type.

A remarkable case occurred in a young Duck three weeks old, in which the lungs, air-sacs, and kidneys were affected, and the growths were already caseating.

2. As before, all the mould-diseases are grouped here. In the Mammals—2 Wallabies and a Kangaroo—it was of the same type as described before, and due to the same organism. The percentage among the Birds remains unchanged : three cases were due to *Aspergillus niger*.

3. The deaths from pneumonia still remain very high, roughly about the same percentage as last year. My impression, from the *post mortems*, is that it is becoming more virulent in the Gardens : there have been more secondary pneumococcal affections,

such as enteritis, nephritis, and gastric ulceration. Many of the Mammals were very rickety and so predisposed. In three of the Reptiles it was due to worms: in all the other cases pneumococcal.

4. One, in a Japanese Ape, was due to pyorrhœa alveolaris: the other two to deep abscesses.

5. Eight of these cases were due to pneumococcal infection.

6. In an Anoa, in which the liver was crammed with flukes.

7. The three birds had all syngamus.

8. Two of these were influenzal, and five had rickets.

9. Nine of the Mammals were badly rickety: in the Birds there was also, in most cases, œdema of the lungs.

There has been a notable decrease of this condition in the Mammals and Birds.

10. The cause of this condition has been traced definitely in one instance, separately to shot, straw, grass, in two to sand, and in seven to worms.

11. The number of cases of enteritis is relatively about the same as last year. In the following instances the cause could be definitely traced: 15 were due to worms, 3 to flukes, 11 to decomposed food, 14 to sand, and 6 to foreign bodies.

12. This occurred in a Fox and a Tasmanian Devil.

13. The two cases in Mammals were in a Wallaroo and in a Kangaroo; in both the primary growth was in the stomach: in the former there were secondary deposits in glands and colon, and in the latter in liver and glands. The reptilian case was a glandular cancer in the stomach of a Tortoise.

14. The two cases of sarcoma in Birds were in a Vulture and a Parrakeet respectively: in the former in liver, pericardium, and heart, and in the latter in the kidney.

15. The diseases grouped under the term "Malaria" were due in the greater number of instances to the *Hæmoproteus danilewski*, in the others to the *Plasmodium præcox*.

16. This occurred in an Alligator after a compound fracture of the thigh.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

February 6th, 1912.

E. G. B. MEADE-WALDO, Esq., Vice-President,
in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

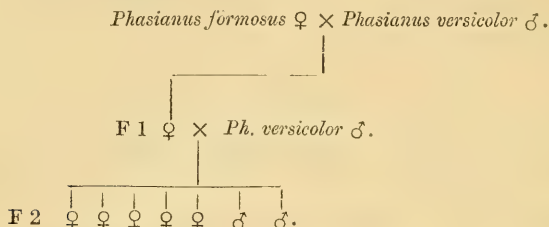
The SECRETARY read a Report on the Additions that had been made to the Society's Menagerie during the months of November and December 1911 and January 1912.

Mr. E. G. B. MEADE-WALDO, V.P.Z.S., exhibited a mounted specimen of a pale fulvous variety of the common wild Polecat (*Putorius putorius*), belonging to the Rev. D. Edmondson Owen, of Llandovery, S. Wales. The animal resembled in colour a well-known variety of the Badger, and was interesting because the Polecats in that particular district were frequently of this peculiar variety and had been well known locally for years.

The SECRETARY read an account of some observations made at the Philadelphia Zoological Garden by Mr. R. D. CARSON, C.M.Z.S., on an instance of retarded development of the fœtus in a Red Kangaroo (*Macropus rufus*).

* This Abstract is published by the Society at its offices, Zoological Gardens, Regent's Park, N.W., on the Tuesday following the date of Meeting to which it refers. It will be issued, along with the 'Proceedings,' free of extra charge, to all Fellows who subscribe to the Publications; but it may be obtained on the day of publication at the price of *Sixpence*, or, if desired, sent post-free for the sum of *Six Shillings* per annum, payable in advance.

Mrs. ROSE HAIG THOMAS, F.Z.S., read a paper dealing with a breeding experiment with Pheasants undertaken to confirm a previous one, in which it had been observed that a male Pheasant had transmitted to his F 2 ♀ offspring the female plumage of his species. The following cross produced the same result :—



The five hens hatched in F 2 had grown up and were all *versicolor* in pattern, colour, dimensions, and moral character. One of these hens had been kept to breed with to test her purity, and the skins of the other four were exhibited together with the skins of a *Ph. formosus* ♀ and a *Ph. versicolor* ♀ for comparison.

The results of these two experiments did not appear to conform to the theory that the cock was homozygous for sex ♂ ♂.

These experiments had also shown that the male had not transmitted to his female F 2 offspring such constant purity of male plumage. In the first experiment, Silver × Swinhoe, out of four males three were “Si. Sw.,” one only pure “Sw.,” and the only two males that lived in the second experiment, *formosus* × *versicolor*, were both “Fo. Ve.”

Mr. J. T. CUNNINGHAM, M.A., F.Z.S., read a paper on Mendelian Experiments on Fowls. The paper described the characters of ten individuals of the F 2 generation reared from a pair of F 1's produced by a cross between Silky ♀ × Bankiva ♂ made by Mr. D. Seth-Smith. The characters recognised were seven in number—namely, colour of plumage, character of plumage (whether silky or normal), comb, pigmentation of skin and internal tissues, toes (*i.e.* presence or absence of extra toe), feathering of legs, crest on head. The Silky of the original cross had white “silky” plumage, rose comb, crest on head, double hallux, feathered legs, and black pigmented skin. The Bankiva had black-red plumage of normal structure, single comb, unfeathered shanks, normal toes, and normal unpigmented skin, no crest. The dominant characters in the F 1 were coloured plumage of normal structure, rose comb with crest, pigmented skin, feathered legs, and double hallux; but several of these characters showed irregular dominance or intermediate condition. The most important results recorded in the paper were imperfect segregation in the F 2 generation in at least two of the characters—namely, the absence of pigmentation in the plumage and the absence of pigmentation

in the skin and tissues. The recessive white of the plumage occurred in four individuals, in all of which, but especially in one, some pigment was present. Only one specimen apparently recessive with regard to the absence of pigmentation in the skin had been examined post mortem, and in this unmistakable traces of pigmentation in the skin and peritoneum were observed. Mr. Cunningham criticised the recent paper by Profs. Bateson and Punnett, in the 'Journal of Genetics,' on the Inheritance of pigmentation of the Silky Fowl, and maintained that the evidence of these authors was not sufficient to prove that segregation in this character was complete in their experiments, and that therefore their results were not necessarily contradictory to his own.

In the absence of Mr. H. G. PLIMMER, F.R.S., F.L.S., F.Z.S. Pathologist to the Society, the SECRETARY read a Report on the Deaths which had occurred in the Society's Gardens during the past year.

Mr. J. LEWIS BONHOTE, M.A., F.L.S., F.Z.S., read a paper on a further collection of Mammals from Egypt, which he had received from Capt. S. S. Flower. The communication dealt with some twenty species, of which the following two were described as new:—

Meriones crassus pallidus, from Atbara, Sudan, similar to *M. crassus sellysii*, from which it differs in its larger size, paler coloration, and more pointed snout.

Acomys russatus aegyptiacus, from the Desert near Cairo. A race of *A. russatus*, from which it differs in its smaller size and much yellower coloration.

Mr. H. WALLIS KEW, F.Z.S., contributed a paper "On the Pairing of Pseudoscorpiones," based on observations made by him on living specimens of *Chelifer* (*Chelifer*) *latreillii* Leach and *Chelifer* (*Chernes*) *cyrneus* L. Koch. Fertilization was found to be effected, without intromission of a copulatory organ, by means of a spermatophore. The male and female faced one another in walking position, the male seizing with one or both palps one or both palps of the female. There was a period of courtship during which *Chelifer* ♂ protruded at intervals long "ram's-horn organs"; and *Chernes* ♂, not possessing these organs, made peculiar movements with one of the palps and with certain of the legs. At length, the spermatophore—which differed in character in the two species—was extruded, and was affixed to the floor, in front of the female, where it stood erect or obliquely. The male then retired by taking a few steps backwards, the female at the same moment coming forwards and receiving the male-product from the spermatophore without delay. Contrary to opinions previously held, the "ram's-horn organs" took no part in the act of fertilization; their function appeared to be excitatory. The modified legs of the first pair of *Chelifer* ♂

were found to be used for seizing the genital-opening of the female at the moment when the spermatophore was approached; there was no corresponding action in the case of *Chernes* ♂, in which the legs exhibited no marked modification.

The next Meeting of the Society for Scientific Business will be held on Tuesday, February 20th, 1912, at half-past Eight o'clock P.M., when the following communications will be made:—

1. A. T. MASTERMAN, M.A., D.Sc., F.Z.S.

Notes on Age-determination in Scales of Salmonoids, with special reference to Wye Salmon. (With lantern illustrations.)

2. H. LYSTER JAMESON, M.A., D.Sc., Ph.D., F.Z.S.

Studies on Pearl-Oysters.—I. The Structure of the Shell and Pearls of the Ceylon Pearl-Oyster (*Margaritifera vulgaris* Schumacher), with an examination of the Cestode Theory of Pearl Production. (With lantern illustrations.)

3. ROBERT SHELFORD, M.A., F.Z.S.

Mimicry amongst the Blattidæ; with a Revision of the Genus *Prosoplecta* Sauss.

4. The Rev. O. PICKARD-CAMBRIDGE, F.R.S., C.M.Z.S.

Contributions to the Knowledge of the Spiders and other Arachnids of Switzerland.

The following papers have been received:—

1. HERBERT L. HAWKINS, M.Sc., F.G.S.

The Classification, Morphology, and Evolution of the Echinoidea Holoctypoida.

2. H. G. PLIMMER, F.R.S., F.L.S., F.Z.S.

Blood-Parasites found in the Zoological Gardens during the four Years 1908-1911.

3. Dr. G. O. Sars, C.M.Z.S.

Zoological Results of the Third Tanganyika Expedition, conducted by Dr. W. A. Cunningham, 1904-1906. Report on some Larval and Young Stages of Prawns from Lake Tanganyika.

4. Mrs. E. W. Sexton.

Amphipoda from Bremerhaven.

5. Robert Broom, M.D., D.Sc., C.M.Z.S.

On the Structure of the Internal Ear, and the Relation of the Basi-cranial Nerves in *Dicynodon*, and on the Homology of the Mammalian Auditory Ossicles.

6. Edward W. Shann, B.Sc.

Observations on some Alcyonaria from Singapore, with a brief Discussion on the Classification of the Family Nephthyidæ.

7. George H. Kenrick, F.Z.S.

A List of Moths of the Family Pyralidæ collected by Felix B. Pratt and Charles B. Pratt in Dutch New Guinea in 1909-10, with Descriptions of new Species.

8. Thomas H. Withers, F.G.S.

Some early Fossil Cirripedes of the Genus *Scalpellum*.

9. Julian S. Huxley.

A First Account of the Courtship of the Redshank (*Totanus calidris*).

10. Frank E. Beddard, M.A., F.R.S., F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidæ.—IV. On Species of *Inermicapsifer* from the Hyrax and on the Genera *Zschokkeella*, *Thysanotænia*, and *Hyracotænia*.

11. Dr. Bashford Dean.

Additional Notes on the Living Specimens of the Australian Lung-fish (*Ceratodus forsteri*) in the Collection of the Zoological Society of London.

Communications intended for the Scientific Meetings should
be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.

February 13th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

February 20th, 1912.

Dr. A. SMITH WOODWARD, F.R.S., Vice-President,
in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

Dr. A. T. MASTERMAN, M.A., F.Z.S., gave a demonstration, illustrated by a large number of lantern-slides, of recent investigations on Age-determination in the Scales of Salmonoids, with special reference to Wye Salmon.

Dr. H. LYSTER JAMESON, M.A., D.Sc., Ph.D., F.Z.S., read a paper "On the Structure of the Shell and Pearls of the Ceylon Pearl-Oyster (*Margaritifera vulgaris*, Schum.); with an Examination of the Cestode Theory of Pearl Production." The author began by reviewing the work on the subject of Pearl Production carried out in Ceylon by Prof. Herdman, F.R.S., and his successors. He examined the theory, enunciated by Prof. Herdman, that most Ceylon "fine" pearls had for their nuclei the remains of cestode larvæ, and that these larvæ, which are abundant in the liver and connective tissues of the Pearl-Oyster in Ceylon, were the "cause" of the most valuable pearls. Dr. Jameson maintained that the evidence adduced in support of this theory by Prof. Herdman and Mr. Hornell was insufficient, and that the only drawings in Prof. Herdman's "Report on the Ceylon Pearl-Oyster Fisheries," published by the Royal

* This Abstract is published by the Society at its offices, Zoological Gardens, Regent's Park, N.W., on the Tuesday following the date of Meeting to which it refers. It will be issued, along with the 'Proceedings,' free of extra charge, to all Fellows who subscribe to the Publications; but it may be obtained on the day of publication at the price of *Sixpence*, or, if desired, sent post-free for the sum of *Six Shillings* per annum, payable in advance.

Society, that purported to show the remains of cestodes in the centres of pearls, were capable of other interpretation. Moreover, he could not find in any of the pearls sectioned by Prof. Herdman, numbering some twenty-five or more, which Prof. Herdman had kindly allowed him to examine, a single instance of a cestode larva forming the nucleus. This observation was borne out by the results of the examination of between 300 and 400 pearls from *Margaritifera vulgaris*, mostly from Ceylon, but also comprising examples from the Persian Gulf, the Gulf of Cutch, the Mediterranean, Madagascar, New Caledonia, etc., none of which, on decalcification, showed cestode or other platyhelminthian larvæ as nuclei. The centre of such a pearl was (where it consisted of material other than the nacre or other normal constituents of the shell) nearly always composed of an abnormal form of shell-substance, analogous to that formed to repair an injury to the shell, which, owing to its opacity, might easily be mistaken for a foreign body.

These repair-substances were sometimes associated with granular matter, the origin of which was obscure; this matter might perhaps be derived from the tissues, or might possibly be of parasitic origin, but Dr. Jameson saw no reason for regarding it as derived from a cestode larva.

Dr. Jameson regarded the presence of these cestodes as a disease parallel to, but independent of, "margarosis"; and compared the case of a pearl-oyster, containing both cestodes and pearls, to that of a man suffering simultaneously from echinococci and scabies, or of a dog infested at the same time with tapeworms and mange.

The author then discussed the systematic position of these cestode larvæ. Prof. Herdman regarded them as a younger stage of a *Tetrarhynchus* larva, which also occurred in the pearl-oyster, and which, acting on this assumption, Shipley named *Tetrarhynchus unionifactor*. The adult of this worm occurred in the Ray (*Rhinoptera javanica*). Here, again, the author maintained that two parallel forms were confused, and that the larva which Herdman thought to be the cause of pearls was not a younger stage of *Tetrarhynchus unionifactor*, but a species referable to *Tylocephalum* or some allied genus. He had found a worm which might be the adult of this larva in the Ray (*Aëtobatis narinari*). This supposed pearl-producing larva, and a similar smaller one, also found in the Ceylon Pearl-Oyster, were described as new species under the names *Tylocephalum ludificans* and *T. minus*.

Preliminary Descriptions.

TYLOCEPHALUM LUDIFICANS, sp. n.

The worm supposed by Prof. Herdman to be the cause of "fine" pearls in the Ceylon Pearl-Oyster. Globular resting scolex, with conical, flattened, or concave myzorhynchus,

usually retracted within a muscular collar, which possesses a denticulated annulus. Average diameter 0.78 mm.; musculature of the myzorhynchus showing no trace of division into bundles; collar-sheath usually widely open in the resting stage.

Resting in fibrous connective-tissue cysts in the tissues of *Margaritifera vulgaris* from the Gulf of Manaar.

TYLOCEPHALUM MINUS, sp. n.

Similar to the above but smaller, average diameter 0.14 mm. As a rule the myzorhynchus appears more conical than in *T. ludificans*, and the collar-sheath more constricted, with smaller aperture, in the resting stage. In some examples the musculature of the myzorhynchus shows a tendency to break up into bundles of fibres.

Habitat as in *T. ludificans*.

Dr. Jameson claimed that he had found *Tylocephalum ludificans* in specimens of the Ceylon Pearl-Oyster in Dr. Kellart's collection in the British Museum, and had considered the possibility of their being concerned with pearl production, and dismissed the theory as untenable, previously to Prof. Herdman's original departure for Ceylon.

The second part of the paper dealt with the structure and formation of the shell and of pearls. The various repair-substances, which replace the ordinary shell substances under abnormal or pathological conditions, were described, their relations to the normal substances of the shell were discussed, and their occurrence in the pseudo-nuclei of pearls dealt with. The "calcospherules" which Herdman regarded as free concretions, and as the cause of "Muscle Pearls," were considered to be in fact minute pearls, composed of the hypostracum, or special shell-substance to which the muscles are attached. This conclusion had been reached independently by Rubbel, in Marburg.

The author said that his observations on the real cause and mechanism which led to the formation of pearls in the Ceylon Pearl-Oyster were still too incomplete to communicate; but he maintained that, as he had already laid down in his 1902 paper, the real cause of pearl production would have to be sought, not in the nuclei or pseudo-nuclei of pearls, but rather in the pathological conditions under which the tissues of the mollusc gave rise to the pearl-sac. It was only in a few cases, like the Trematode pearls in the common mussel, that the cause of the pearl-sac, *i.e.* in this case the trematode, frequently remained to form the "nucleus" of the pearl and tell the tale of its origin.

The author had found that, as observed by Prof. Herdman, a minority of Ceylon pearls may have foreign bodies, such as sand-grains, in their centres.

Mr. R. SHELFORD, M.A., F.Z.S., communicated a paper on "Mimicry amongst the Blattidæ; with a Revision of the Genus *Prosoplecta* Sauss.," in which he dealt with a number of exceptions to this usually cryptically coloured type of Cockroach, and in greater detail with the *Prosoplecta*, nearly all the members of which presented a remarkably close and detailed resemblance to other insects.

A paper entitled "A Contribution to the Knowledge of the Spiders and other Arachnids of Switzerland," was contributed by the Rev. O. PICKARD-CAMBRIDGE, M.A., F.R.S., F.Z.S. It was based on a number of specimens collected for the author by various persons, at different times, and contained the description of one new species.

The next Meeting of the Society for Scientific Business will be held on Tuesday, March 5th, 1912, at half-past Eight o'clock P.M., when the following communications will be made:—

1. Exhibitions and Notices.

2. HERBERT L. HAWKINS, M.Sc., F.G.S.

The Classification, Morphology, and Evolution of the Echinoidea Holoctypoida. (With lantern illustrations.)

3. H. G. PLINMER, F.R.S., F.L.S., F.Z.S.

Blood-Parasites found in the Zoological Gardens during the four Years 1908–1911. (With lantern illustrations.)

4. Dr. G. O. SARS, C.M.Z.S.

Zoological Results of the Third Tanganyika Expedition, conducted by Dr. W. A. Cunningham, 1904–1906. Report on some Larval and Young Stages of Prawns from Lake Tanganyika.

5. ROBERT BROOM, M.D., D.Sc., C.M.Z.S.

On the Structure of the Internal Ear, and the Relation of the Basi-cranial Nerves in *Dicynodon*, and on the Homology of the Mammalian Auditory Ossicles.

The following papers have been received :—

1. EDWARD W. SHANN, B.Sc.

Observations on some Aleyonaria from Singapore, with a brief Discussion on the Classification of the Family Nephthyidae.

2. GEORGE H. KENRICK, F.Z.S.

A List of Moths of the Family Pyralidae collected by Felix B. Pratt and Charles B. Pratt in Dutch New Guinea in 1909-10, with Descriptions of new Species.

3. THOMAS H. WITHERS, F.G.S.

Some early Fossil Cirripedes of the Genus *Scalpellum*.

4. JULIAN S. HUXLEY.

A First Account of the Courtship of the Redshank (*Totanus calidris*).

5. FRANK E. BEDDARD, M.A., F.R.S., F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidea.—IV. On Species of *Inermicapsifer* from the Hyrax and on the Genera *Zschokkeella*, *Thysanotenia*, and *Hyracotenia*.

6. DR. BASHFORD DEAN.

Additional Notes on the Living Specimens of the Australian Lung-Fish (*Ceratodus forsteri*) in the Collection of the Zoological Society of London.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.

February 27th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

March 5th, 1912.

Sir JOHN ROSE BRADFORD, M.D., D.Sc., F.R.S.,
Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

Mr. OLDFIELD THOMAS, F.R.S., F.Z.S., exhibited the skull of a German Wild Boar from Baden and of a Hungarian Wild Boar from Kolozsvár, the latter recently presented to the British Museum by Fräulein Sarolta von Wertheimstein.

The difference in size between these was so great that Mr. Thomas considered that the Hungarian Boar should be separated as a distinct species, which he proposed to call *Sus attila*.

He also stated that the North and South Spanish Wild Boars were, on the other hand, so much smaller in different degrees than the German animal as each to deserve subspecific distinction from the latter.

The three forms now described were therefore as follows:—

SUS ATILA, sp. n.

Upper length of skull 452 mm.; height of skull on lower jaw 271.

Hab. Hungary and Russia. Type locality Kolozsvár.

Type. Male. B.M. No. 12.1.23.1

SUS SCROFA CASTILIANUS, subsp. n.

Upper skull length 353 mm.; height 198.

Hab. North Spain. Type locality Burgos.

Type. Male. B.M. No. 11.10.5.3.

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SUS SCROFA BÆTICUS, subsp. n.

Upper skull length 324 mm.; height 208.

Hab. South Spain. Type locality Coto Doñana.

Type. Male. B.M. No. S.3.8.12.

Mr. H. L. HAWKINS, M.Sc., F.G.S., read a paper, communicated by Dr. Henry Woodward, F.R.S., V.P.Z.S., on "The Classification, Morphology, and Evolution of the Echinoidea Holactypoida," illustrated with lantern-slides. The classification of the Mesozoic Gnathostomatous Irregular Echinoids was revised, with diagnoses of the families, subfamilies, and genera, and a new genus and subgenus were introduced. The anatomy of the test was described for the Holactypoida, and compared with that of other Orders. The origin of the Irregular Echinoids was discussed, and the lines of evolution that they followed were indicated and summarized in a genealogical table.

Mr. H. G. PLIMMER, F.R.S., F.Z.S., Pathologist to the Society, read a paper "On the Blood-Parasites found in the Zoological Gardens during the four years 1908-1911," illustrating his remarks with a large number of lantern-slides. The paper contained the results of examination of the blood of 6430 animals, in about 7 per cent. of which parasites were found. Many of these parasites were described for the first time, and in other cases the hosts were newly recorded.

Prof. G. O. SARS, C.M.Z.S., presented a memoir entitled "Zoological Results of the Third Tanganyika Expedition, conducted by Dr. W. A. Cunningham, 1904-1906. Report on some Larval and Young Stages of Prawns from Lake Tanganyika."

Four forms were dealt with in this paper, two of which represented very early larval stages, and apparently belonged to two quite different kinds of Prawns, but owing to the difficulty of deciding with any certainty the species or even the genera to which they were referable, they were not named, although a detailed description was given and their probable origin suggested. The remaining two forms represented a larva in the last stage and a very young Prawn in the first post-larval stage, and both were referred to a definite species.

Dr. ROBERT BROOM, D.Sc., C.M.Z.S., communicated a paper "On the Structure of the Internal Ear, and the Relation of the Basi-cranial Nerves in *Dicynodon*, and on the Homology of the Mammalian Auditory Ossicles," the first part of which contained an account, the first on record, of the *bony labyrinth* enclosing the internal ear and the nerve foramina in relation thereto, in the skull of the extinct Reptile, *Dicynodon*. The author had obtained a cast of the internal ear of a specimen in which the matrix was

hardened by epidote and the bone mainly calcareous. By dissolving away the calcareous matter replacing the bone, he had satisfactorily traced the structure of the ear. The author stated that the vestibule was very remarkably elongated and that there was no trace of a cochlea. The semicircular canals were of the normal reptilian type.

The homologies of the auditory ossicles were discussed, and it was shown that the bone which Dr. Broom had formerly regarded as the tympanic was really the stapes. In the light of his new observations the author stated that he was now prepared to accept the view that the incus is the homologue of the reptilian quadrate, the malleus the articular, and the tympanic the angular.

The next Meeting of the Society for Scientific Business will be held on Tuesday, March 19th, 1912, at half-past Eight o'clock P.M., when the following communications will be made:—

1. A. RADCLIFFE DUGMORE, F.R.G.S.

Lantern Exhibition of Studies of Wild Animals in Africa and North America.

2. EDWARD W. SHANN, B.Sc.

Observations on some Alcyonaria from Singapore, with a brief Discussion on the Classification of the Family Nephthyidae.

3. GEORGE H. KENRICK, F.Z.S.

A List of Moths of the Family Pyralidae collected by Felix B. Pratt and Charles B. Pratt in Dutch New Guinea in 1909-10, with Descriptions of new Species.

4. THOMAS H. WITHERS, F.G.S.

Some early Fossil Cirripedes of the Genus *Scalpellum*.

The following papers have been received:—

1. JULIAN S. HUXLEY.

A First Account of the Courtship of the Redshank (*Totanus calidris*).

2. FRANK E. BEDDARD, M.A., F.R.S., F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidea.—IV. On Species of *Inermicapsifer* from the Hyrax and on the Genera *Zschokkeella*, *Thysanotenia*, and *Hyracotenia*.

3. DR. BASHFORD DEAN.

Additional Notes on the Living Specimens of the Australian Lung-Fish (*Ceratodus forsteri*) in the Collection of the Zoological Society of London.

4. MRS. E. W. SEXTON.

Amphipoda from Bremerhaven.

5. W. M. SMALLWOOD and ELIZABETH G. CLARK.

Chromodoris zebra Heilprin, a distinct Species.

6. C. TATE REGAN, M.A., F.Z.S.

Descriptions of new Fishes of the Family Loricariidae in the British Museum Collection.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.
March 12th, 1912.

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NOTICE.

The 'Proceedings' for the year are issued in four parts, paged consecutively, so that the complete reference is now P. Z. S. 1912, p. . . . The Distribution is as follows:—

Part	I.	issued in	March.
"	II.	"	June.
"	III.	"	September.
"	IV.	"	December.

'Proceedings,' 1911, Part IV. (pp. 869-1213), were published on December 15th, 1911.

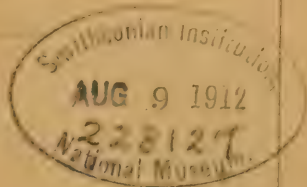
'The Abstracts of the Proceedings,' Nos. 103 to 105, are contained in this Part.

PROCEEDINGS
OF THE
GENERAL MEETINGS FOR SCIENTIFIC BUSINESS
OF THE
ZOOLOGICAL SOCIETY
OF LONDON.
1912.

PART II.

CONTAINING PAGES 241 TO 504, WITH 28 PLATES
AND 31 TEXT-FIGURES.

JUNE 1912.



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THE ZOOLOGICAL SOCIETY OF LONDON.

THIS Society was founded in 1826 by Sir STAMFORD RAFFLES, Mr. J. SABINE, Mr. N. A. VIGORS, and other eminent Naturalists, for the advancement of Zoology and Animal Physiology, and for the introduction of new and curious subjects of the Animal Kingdom, and was incorporated by Royal Charter in 1829.

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The Meetings of the Society for General Business are held in the Meeting Room at the Society's Office on the third Wednesday in every month of the year, except in September and October, at half-past Four o'clock P.M.

The Meetings for Scientific Business are held in the Meeting Room at the Society's Office fortnightly on Tuesdays, except in July, August, September, and December and January, at half-past Eight o'clock P.M.

The Anniversary Meeting is held on the 29th. of April, or the nearest convenient day, at Four P.M.

The Society's Gardens are open daily from Nine o'clock until Sunset. Mr. R. I. Pocock, F.R.S., F.L.S., is the resident Superintendent and Curator of Mammals, Mr. D. Seth-Smith is Curator of Birds and Inspector of Works, and Mr. E. G. Boulenger is Curator of Reptiles. The Prosectorium for Anatomical and Pathological work is under the charge of Mr. Frank E. Beddard, M.A., D.Sc., F.R.S., Prosector, assisted by Mr. H. G. Plimmer, F.R.S., M.R.C.S., Pathologist to the Society.

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FELLOWS also have the privilege of subscribing to the Annual Volume of 'The Zoological Record,' which gives a list of the Works and Publications relating to Zoology in each year, for the sum of One Pound Ten Shillings. Separate divisions of volumes 39 to 42 can also be supplied. Full particulars of these publications can be had on application to the Secretary.

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Any FELLOW, having paid all fees due to the Society, is at liberty to withdraw his or her name upon giving notice in *writing* to the Secretary.

Ladies or Gentlemen wishing to become Fellows of the Society are requested to communicate with "The Secretary."

P. CHALMERS MITCHELL,

Secretary.

Regent's Park, London, N.W.,
June, 1912.

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OF THE
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FOR
SCIENTIFIC BUSINESS.

1912.

TUESDAY, OCTOBER 29
,, NOVEMBER 12 & 26

*The Chair will be taken at half-past Eight o'clock in the Evening
precisely.*

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LIST OF PUBLICATIONS.

THE scientific publications of the Zoological Society of London are of two kinds—"Proceedings," published in an octavo form, and "Transactions," in quarto.

According to the present arrangements, the "Proceedings" contain not only notices of all business transacted at the scientific meetings, but also all the papers read at such meetings and recommended to be published in the "Proceedings" by the Committee of Publication. A large number of coloured plates and engravings are issued in the volumes of the "Proceedings," to illustrate the new or otherwise remarkable species of animals described therein. Amongst such illustrations, figures of the new or rare species acquired in a living state for the Society's Gardens are often given.

The "Proceedings" for each year are issued in four parts, paged consecutively, in the months of March, June, September, and December. From January 1901 they have been issued as two half-yearly volumes, indexed separately.

An "Abstract of the Proceedings" is published by the Society on the Tuesday following the date of Meeting to which it refers. It is issued along with the "Proceedings," free of extra charge, to all Fellows who subscribe to the Publications, but it may be obtained on the day of publication at the price of Sixpence, or, if desired, sent post free for the sum of Six Shillings per annum, payable in advance.

The "Transactions" contain such of the communications made to the scientific meetings of the Society as, on account of the nature of the plates required to illustrate them, are better adapted for publication in the quarto form. They are issued at irregular intervals.

Fellows and Corresponding Members, upon payment of a Subscription of One Guinea *before* the day of the Anniversary Meeting in each year, are entitled to receive the Society's Publications for the year. They are likewise entitled to purchase the Publications of the Society at 25 per cent. less than the price charged for them to the Public. A further reduction of 25 per cent. is made upon purchases of Publications issued prior to 1881, if they exceed the value of five pounds.

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P. CHALMERS MITCHELL,
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INDEX ZOOLOGICUS, No. II. An alphabetical list of names of genera and subgenera proposed for use in Zoology, as recorded in the 'Zoological Record,' Vols. 38-47 inclusive (1901-1910), and the Zoology volumes of the 'International Catalogue of Scientific Literature,' Annual Issues 1-10. Compiled (for the Zoological Society of London) by CHARLES OWEN WATERHOUSE and edited by DAVID SHARP, M.D., F.R.S. London, 1912. Price to Fellows, 12s. 6d. net; price to the public, 15s. net.

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P. CHALMERS MITCHELL,

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REGENT'S PARK, LONDON, N.W.

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17. Mendelian Experiments on Fowls.

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[Received October 25, 1911: Read February 6, 1912.]

I. EXPERIMENT 1.—*Bankiva* ♂ × *Silky* ♀.

Crosses between Silky fowls and other breeds have frequently been tried, both before and since the formulation of the Mendelian doctrine. The silky character of the feathers has always been found to be recessive, and this was noticed before the recently awakened interest in Mendel's theory. Thus Tegetmeier (1867, p. 224) found that the F_1 hybrids of Silkies with other breeds had normal plumage, and Darwin (1876, chap. vii.) noted the same result in the offspring of a white Silky hen mated to a Spanish cock.

Bateson (1909, pp. 34, 35, 181) mentions the heredity of the comb, of the silky character, and of the pigmentation of the skin, describing experiments on the latter character in detail. He also discusses (ibid. p. 103) the heredity of the white colour of the Silky. Bateson's results and conclusions will be discussed in reference to the results of the experiment here recorded. C. B. Davenport (1906, p. 55) describes a cross between Silkies and Frizzled fowls, but he reared only the direct offspring of the cross, the F_1 generation.

My experiment was made with a pair of F_1 's kindly given to me by Mr. D. Seth-Smith. These had been reared in the Society's Gardens from a cross between a male of the Jungle Fowl (*Gallus bankiva*) and Silky hens, and my attention was called to the interest of this cross by Mr. Frank Finn, F.Z.S. The Jungle cock may not have been perfectly pure bred, but there is no evidence that its pedigree was impure. The characters of these original parents are as follows:—

Jungle Fowl ♂.

Comb, single.

Colour of plumage, black-red: breast and tail-feathers black, neck and saddle hackles yellowish red.

Skin, unpigmented: comb and wattles red.

Legs, clean, not feathered.

Feet, normal, four toes on each.

No crest on head.

Silky Fowl ♀.

Comb, small, rose.

Colour of plumage, white.

Skin, black; comb and wattles black-red, ear-lobes blue.

Legs, feathered.

Feet, with double hallux on both.

Crest of feathers on head behind comb.

Thus, including the silky character of the feathers, contrasted with the normal, we have seven pairs of characters the heredity of which is to be investigated.

In the F_1 specimens the following characters are dominant :—

- Coloured plumage.
- Normal structure of plumage.
- Rose comb.
- Black pigmentation of skin.
- Double hallux.
- Feathering of legs.
- Crest on head.

But the dominance is somewhat irregular. Thus, one hen of F_1 at the Gardens had a single comb. Several of the F_1 's had a normal foot on one side and a double hallux on the other. The majority had the double hallux on both sides. In my pair the cock has both feet normal and the hen has both feet abnormal, with double hallux. This irregularity of dominance of the extra toe has been noticed by previous experimenters. The crest is dominant, but much smaller in the F_1 's than in the Silky. The skin in my pair is pigmented, but not so dark as in the Silky; it looks blue instead of black. The feathered leg is dominant, the feathering being present in all the F_1 's but the feathering is less than in the Silky. These facts on the whole agree with the idea of dominance as the presence of a positive character (presence and absence theory of dominant and recessive), which in the F_1 is present only in one half of the zygote, *i. e.*, in one of the gametes which are united in the cross, and therefore naturally does not produce so much effect as when it is carried by both gametes. Thus the crest, the feathering of the legs, and the pigmentation of the skin may be said to be intermediate in F_1 between the conditions in the two parents. The dominance, however, seems sometimes to fail, as in the case of the specimen with a single comb, and the specimens with double hallux on one foot only or on neither. The failure of dominance of the rose comb is not mentioned by Bateson, who states that the dominance of the rose comb is very definite and that it is generally quite impossible to distinguish pure rose from the heterozygous type containing single. On the other hand, exceptions to the dominance of the extra toe are common, and are mentioned by Bateson, who states that it occurs in all cases yet studied in birds and mammals.

In all F_1 specimens the coloured plumage and the normal structure of the feathers are present; these characters are completely dominant.

In other crosses which have been described in the experiments above referred to much greater irregularity of dominance has been observed. Thus Bateson found, with regard to the pigmentation of the skin, that when the Silky hen was crossed with a Brown Leghorn cock all the F_1 offspring, both male and female,

were either destitute of pigmentation or showed only a small amount of it in certain parts. But when the opposite cross was made, Silky cock with Brown Leghorn hen, the F_1 males had unpigmented skins, while the females were almost as much pigmented as the pure Silky hens. Bateson explains these results by the assumption that there are three pairs of characters or allelomorphs affecting the results, namely :—

Presence and absence of femaleness.

Presence and absence of the black pigmentation.

Presence and absence of a factor which can suppress or mask the development of the pigmentation.

He assumes that this last factor is double or homozygous in the Brown Leghorn cock, single or heterozygous in the Brown Leghorn hen, and absent in the Silky. There is no need for such assumptions in the case of the Bankiva cock, but it must be noted that I have no experience of the opposite cross, Bankiva hen with Silky cock.

In the experiment here considered the white colour of the Silky plumage is perfectly recessive. This result also differs somewhat from that of previous experiments. Davenport crossed a Silky cock with Frizzled hens, but he states that the colour of Frizzles is not constant but variable. His hens were of various colours—dark brown, yellowish, light brown, and mixed black yellow and red. Some of them may have been carrying white as a recessive. Of his F_1 hybrids 7 were white and 25 coloured. Davenport considers that the results do not agree with either the hypothesis that white is recessive or that it is dominant. He concludes that the white is not always dominant, but this seems to be a slip: he probably means that the colour is not always recessive.

Bateson found that the white of the Silky, though recessive to colour, gave coloured offspring when crossed with certain other recessive whites obtained from crossings. He concludes, therefore, that the whiteness of the Silky is due to the absence of one of two elements which together produce colour. We shall have to consider this point again in discussing the colours of the F_2 's which form the point of chief interest in my results.

We now come to the consideration of the F_2 generation, that is of the chicks which I have hatched and reared from the pair of F_1 's above mentioned. The first brood was hatched on May 15th, 1911, and consisted of nine chicks, one of which died within the first few days; the other eight are still alive and vigorous. The hen afterwards sat again, but this time hatched only two chicks, probably in consequence of the very dry weather; these two were hatched in August. The following table (p. 244) shows the characters of these chickens.

The numbers of these specimens are, of course, too small to afford evidence of any importance with regard to the numerical proportions in which the characters or combinations of characters

Cross Silky ♀ × Bankiva ♂.
F₂ generation.

	Colour of Plumage.	Structure of Plumage.	Comb.	Pigmentation of Skin.	Toes.	Feathering of Legs.	Crest.
1. ♂.	White.	Normal.	Rose.	Black.	Normal.	Much feathered.	None.
2. ♂.	White.	Silky.	Rose.	Normal.	Double hallux on both feet.	Moderately feathered.	Slight.
3. ♂.	Coloured.	Silky.	Rose.	Black.	Normal.	Moderately feathered.	Crest.
4. ♂.	Coloured.	Normal.	Rose.	Normal.	Normal.	Moderately feathered.	Crest.
5. ♂.	Coloured.	Normal.	Single.	Black.	Normal.	A trace of feathering.	Slight.
6. ♀.	Coloured.	Normal.	Single.	Black.	Normal.	Moderately feathered.	Crest.
7. ♀.	Coloured.	Normal.	Rose.	Black.	Normal.	Moderately feathered.	None.
8. ♀.	Coloured.	Normal.	Single.	Black.	Normal.	Moderately feathered.	Crest.
Second Brood.							
9. ♀.	White.	Normal.	Rose.	Black.	Normal.	Feathered.	Crest.
10. ♂.	White.	Silky.	Rose.	Normal.	Normal.	Quite clean.	Crest.

occur, and it is not the object of this paper to draw conclusions as to factors or segregation from the numerical proportions. It is assumed that characters united in F₁ tend to segregate in F₂, and that the explanation of this segregation is the separation in the gametes of F₁ of the pairs of factors, so that half the gametes

contain one character and the other half its allelomorph, as it is called. My object here is merely to draw attention to certain points in my results which indicate that the segregation is not necessarily complete. If we consider single characters and take only the eight chicks of the first brood, omitting the one that died, and the two of the second brood, we see that the Mendelian proportion of 3 dominants to 1 recessive is, in many of the characters, either exactly or approximately exhibited. Thus we have in the colour of the plumage 6 coloured to 2 white, in the structure of the feathers 6 normal to 2 silky, in the combs 5 rose to 3 single, in the colour of the skin 6 black to 2 normal, in the crest 6 with crest to 2 without. The double hallux, however, occurs only once, instead of six times, and as the male F_1 had normal feet although the extra toe character was present in the cross, it is by no means certain that this character was segregated in his gametes. The feathering of the legs and the crest on the head exhibit a condition which does not harmonise exactly with the Mendelian theory. The leg-feathering is present in all the specimens except No. 10 in the second brood, but it exhibits very different *degrees* of development. One explanation of this may be that such a character is naturally more developed in the dominant homozygote, where the character was present in both gametes, than in the heterozygote, where it was present only in one, and this is probably the case. But there is one specimen, No. 5, in which the feathering is the merest trace, and Mendelism affords no explanation of such variations within a character, it merely takes account of its presence or absence. Similar remarks may be made concerning the crest: of the 8 chicks of the first brood there are 6 with crest and 2 without, the Mendelian proportion, and there are 4 with well-developed crest and 2 with a very slight crest. The latter may be the heterozygotes for this character, although there should be four of these to two dominant homozygotes.

I have noticed an interesting correlation between the crest and the character of the comb. As Bateson points out, the rose comb of the Silky has its posterior end divided into three irregular points. He describes the comb as a rose plus a trifid element which is the cause of this condition of the posterior end, and states that in F_2 from Silky \times Single, regular rose combs are produced in those individuals which have the rose factor without this trifid element. In other words, the comb of the Silky is represented not by one factor but by two. The regular or ordinary rose comb, as it occurs in Hamburg fowls, has a flat upper surface which is triangular in shape, the apex of the triangle, called the peak or pike, being free from the head and projecting backwards. Bateson's statements are for the most part confirmed by my results, but I have a somewhat different interpretation to offer. The rose comb of the Silky is not only trifid posteriorly but abbreviated. This character occurs in both the F_1 's in my experiment; it is dominant. In the F_2 's the same character

occurs in all those that have a crest, both males and females, although the comb is much smaller in the hens. The two specimens without a crest, on the other hand, No. 1 ♂ and No. 7 ♀, have the normal rose comb with a projecting point behind. The crest makes no difference to the shape of the single comb. There is thus a correlation between the crest of feathers and the truncated trifid character of the rose comb: these two characters either occur together or are absent together. I believe, however, that this is not a coupling of two distinct characters but that they are both manifestations of one character. What Bateson calls a trifid element is in my opinion nothing but the crest; the factor which causes the development of the crest of the feathers also causes the posterior truncation of the comb.

The most remarkable and interesting result in my experiment is the condition of the recessive whites in the first brood of F_2 's. Both of these whites show some colour, while according to the Mendelian theory of segregation they ought to show none. The specimen No. 1, now (Sept. 30, 1911) $4\frac{1}{2}$ months old and in mature plumage, has a band of colour across the back behind the shoulder; when I first noticed this colour it was a very pale yellowish tinge, so slight that it was difficult to be sure that it was actually pigment in the feathers and not accidental staining. Now it is darker and more orange, and there is also a slight yellow tinge in the neck hackles. The other white, No. 2, has also some slight colouring, a faintly tinted region on the back like the other, and some very pale patches on the neck ventrally and over the eye on each side. These white specimens were yellowish white in the down when first hatched, but this is no evidence of colour, for the down of the chicks of white fowls, as of white ducks, is always yellowish. The two whites of the second brood do not yet show any colour.

Now this fact shows that the Mendelian doctrine of complete segregation and gametic purity is not always true. The fact that these recessive whites do appear in the F_2 generation shows clearly that gametic segregation does take place in the F_1 individuals, but in my experiment the recessive white is not exactly the same as the original white of the Silky: it is no longer pure, but is mixed with a little of the colour factor with which it has been mixed in F_1 . We must consider whether the result obtained by me is explained in any degree by Bateson's conclusion concerning the white of the Silky. As already mentioned, he concludes that this white is due not to the absence of all colour factors, but to the absence of one out of two which together produce colour. Now this partial colour factor cannot explain my result, for it cannot by itself produce any colour, and the essential point of the Mendelian doctrine is that the recessive individual in F_2 is homozygous, *i. e.* due to the union of two gametes each of which carries the factor for the recessive character. The recessive character in the case under consideration is the white of the Silky, and the white in the individuals

of F_2 which I have described is not the same as the white of the original Silky. Bateson states that the adult Silky is pure white as a rule, but the down of the chickens has some colour usually though perhaps not always. The colour in this case is buff, not blue or black, and it occurs on the sides of the head and on the rump. This again has nothing to do with the result I have described, for the colour in my F_2 whites was not observed in the chicks, or in the mature plumage when first developed, but appeared later, and gradually increased in intensity. I have not examined pure Silky chicks, as I have not reared any.

It is, I think, certain that in this particular case the recessive character derived from a cross is not pure, and this naturally suggests that no recessives derived from crosses are perfectly pure. The determinants of these characters in the hybrid individuals have been mixed in the F_1 individuals with the determinants of other characters. Whatever the determinants may be, whether special chemical compounds such as ferments, or parts of chromosomes, it is possible that the mixing in F_1 is such that each determinant is affected, tainted as it were by the other. If this were the case it would tend to throw doubt on the whole conception of species and varieties reared on the Mendelian phenomena. It may be that segregation occurs not because the determinants or factors in the gametes are indivisible units, but because the determinants of certain pairs of characters are too different to mix completely, while others less different would show more mixture. In any case the recessive white in my experiment is not pure, and it is improbable that it is the only case of its kind. I hope next season to breed from these whites and study the heredity of the colour character in the F_3 generation.

Prof. Punnett, in conversation with me on this subject, made two different suggestions in explanation of the colour in the white recessive. The first was that the Silky is not a perfectly white breed, but normally carries a little yellow colour, which is usually present in the cocks but not in the hens. As the stock of Silkies from which my cross came were all hens, and I have no experience of Silky cocks, I cannot disprove this suggestion, but can only point out that it does not agree with the account of Silkies given by Davenport, nor with that given in Wright's 'Book of Poultry,' which says the plumage should be pure white. The second suggestion was that the yellow or yellow to red colour of the Bankiva might be a distinct factor from that of the black pigment, and therefore be segregated independently. This seems to me an untenable hypothesis, as, if it were true, we ought to get wholly black and wholly yellow or red birds in F_2 , and no such cases have occurred. Moreover, the F_2 bird No. 1 in my experiment has produced one or two single feathers on the back which contain black pigment as well as yellow. I have plucked out one such feather and preserved it.

EXPERIMENT 2.—*Japanese Long-tail* ♂ × *Dorking* ♀.

The second experiment I have to describe was chronologically the earlier, but is less complete and less important than that already described. It consisted in crossing a Japanese Long-tailed cock with a Dorking hen. Crosses between the Long-tailed fowls and other breeds have been previously made by C. B. Davenport at the Carnegie Station for Experimental Evolution at Cold Spring Harbour, New York, U.S.A. ('Inheritance in Poultry,' Washington, 1906). In his first experiment Davenport crossed a cock of the Long-tailed breed, which he refers to by its proper Japanese name of Tosa fowl, with a White Cochinchina Bantam hen. Six F_1 's were reared, 3 cocks and 3 hens. The males were all of the male Tosa-fowl coloration except that every feather was repeatedly barred with white. The females were all of the female Tosa-fowl coloration except that the light shafting was very much broadened. The female Tosa in this case is described as "black mottled with rusty with a straw-coloured shaft to each feather." All three males developed abnormally long middle tail-feathers, in other words the tail character of the Tosa was dominant.

Of the F_2 generation 57 individuals were hatched: of these 16 were white and 41 pigmented, which approximates to the theoretical proportion of one in four. But of the 16 whites only 5 were without trace of reddish pigment, which occurred on the breast, top of head, and remiges. Davenport draws from this the same conclusion that I have suggested in the case of my cross between Silky and Jungle fowl, namely that segregation is not always perfect, and the gametes from which these whites arose were not pure for the white character. As the F_2 's were immature at the time of publication, the inheritance of the long-tailed character in this generation could not be described.

With regard to the F_1 's, Davenport points out that the two sexes, except for the admixture of the white colour, resemble the male and female Tosa fowl respectively, and remarks that from a germ-cell of the male Tosa either a bird coloured like a male Tosa or one coloured like a female Tosa may arise, that the male germ-cells contain the Anlagen not only of the male characteristic but also of the female characteristic. The same result is equally evident in the results of my cross between the male Jungle fowl and the White Silky, the hens in F_1 and the coloured ones in F_2 showing the coloration and markings of the female Jungle fowl. This conclusion is in opposition to the Mendelian view that the female is heterozygous but the male homozygous, the latter not carrying the female character. Mendelians argue that the effects of castration in male vertebrates generally can be explained as merely the non-appearance of male characters, and they would probably maintain that the coloration of the hens referred to in these cases was merely the absence of the male characters. But it is necessary to distinguish between

somatic or secondary characters and the actual sex. It is certain that the somatic characters of the female of a particular breed are actually transmitted by the male, and there are no facts known which support the assumption that positive characters, if the female possessed them, would not be transmitted in the same way.

In a second experiment Davenport crossed the Tosa male with a female dark Brahma. In this case only the F_1 generation was reared, namely 16 males and 5 females. In some of the male hybrids the tail-feathers showed greater length than those of the adult Brahma, but as they were only six months old at the time the Report was written, the inheritance of the tail character was not completely known.

In my cross between the Tosa cock and Dorking hen only three F_1 chicks were hatched and reared in 1905. They were all hens. Two of them had the double hallux which occurs in the Dorking, on both sides, the third on one side only. The combs were larger than those of the Japanese hens; the coloration was speckled much like that of the Japanese hens, each feather with a light shaft, but the coloration of the Dorking hen is not very different, and I did not pay much attention to this character.

In 1906 the three F_1 hens were kept with a pure-bred Japanese cock. The eggs of the hybrids were brown in shell-colour, while those of the old Dorking hen were white. The egg-colour of the Japanese was therefore dominant. This is another case for the Mendelians to consider. Surely the colour of the egg-shell must be a female character, and here it is transferred to the female hybrids by the male. The eggs were also smaller than those of the Dorking, another egg character derived from the Japanese cock.

Two broods of F_2 's, *i. e.* F_1 ♀ \times Jap. ♂, were reared. In the first brood 5 chicks were hatched and 3 died in the egg: two of the 5 had the double hallux, three had normal toes, all those in the egg had normal toes. Thus the number with double hallux was 2 out of 8, whereas the expectation, as the character is dominant, was equal numbers of each character. Ultimately three of these chicks were reared, and all were cocks, one with double hallux, two with normal toes.

The second brood hatched consisted of 11 chicks, of which 3 had the double hallux and 8 had normal toes. The two broods together therefore give 5 with double hallux to 14 with normal toes, where the expectation was equal numbers. Of the second brood 5 were cocks and 6 hens. Thus of the F_2 's there were in all 8 cocks, and if the long tail was dominant every one would show it, while if it were recessive half would have the long tail and half the short tail of the Dorking. The result showed that the character was dominant, as it was recognised in all the birds except one which died before the character was definitely visible.

One cock and five hens of these F_2 's were kept to breed from,

all of them with normal toes, all those with the extra toe having been killed off. From these were hatched and reared in 1907 5 F_3 's (2 cocks and 3 hens), and in 1908 8 F_4 's (3 cocks and 5 hens). In all these cocks the Japanese character of the tail was observed, although they were not all kept long enough to develop any great length of feathers. The result, however, is not conclusive with regard to segregation or absence of segregation in the tail character, for the F_2 cock bred from F_1 ♀ and Japanese ♂ might itself have been a pure dominant in this character, in which case all the F_3 's would have been either homozygous or heterozygous dominants. Similarly, the F_3 ♂ kept for breeding might have been a homozygous dominant, and segregation would then not be evident in F_4 . A complete experiment to test the segregation of the Japanese Long-tail character is therefore yet to be made.

The double hallux did not reappear in any of the F_3 or F_4 generations, which supports the view that the normal toe in the F_2 's is a pure recessive.

II. *Incomplete Segregation of the Pigmentation of the Silky Fowl.*

In Part I. of this paper, when describing the characters of the F_2 generation from a cross between Bankiva male and Silky female, I treated the inheritance of the peculiar pigmentation of the Silky as a case of simple segregation. When I wrote that part, I had only examined the F_2 birds in the living condition, in which there is a conspicuous contrast between the sooty colour of the combs and wattles in the majority and the blood-red colour of the others which seemed obviously recessives. Afterwards it occurred to me that if there were incomplete segregation in the colour of the plumage the recessives in other characters also might be impure. I was led to consider the possibility of slight degrees of body pigmentation by the description of such degrees given by Bateson and Punnett in their recent paper in the 'Journal of Genetics,' vol. i. no. 3. Accordingly I killed No. 10 of the F_2 's, which had the white colour and silky character in its plumage, and apparently normal colour in comb and skin, that is to say the comb etc. was blood-red, and the skin, so far as could be seen between the feathers, unpigmented. Before the bird was plucked, however, I noticed a ring of dark colour on the lips of the cloacal aperture. On further examination I found considerable pigmentation of the subcutaneous tissue of the abdomen behind the sternum, which was the cause of the darkening, above mentioned, of the lips of the cloaca. There was subcutaneous pigment on the tarsal joint and all down the tarso-metatarsus, but none on the knee-joint. It occurred also on the elbow-joint of the wing and on the wrist-joint, but not at the shoulder-joint. In all these cases the pigment was visible externally as a darkening of the skin, and under the microscope

as a reticulum of pigment cells in the connective tissue. On the peritoneum the pigmentation was slight but distinct, not only on the outer wall but also over the intestines, for example over the gizzard; the surface of the testes was also black over the anterior three fourths of the organs, while the posterior fourth was white.

The next thing to be done was to make a thorough examination of a normal specimen of *Gallus bankiva* in order to compare it with the recessive just described. Fortunately, the cock of the original cross being now rather old and blind of one eye, was available for the purpose and was placed at my disposal and killed and plucked. I found a little pigment in the subcutaneous tissue about the ankle-joint posteriorly, but none in the periosteum: this pigment was merely a slight extension of the pigment on the inner surface of the skin, which extended down the tarso-metatarsus as in the F_2 recessive. In both cases the shanks appeared externally olive-green. In the Bankiva there was no pigmentation anywhere else, either in the subcutaneous tissue of the abdomen or of the wing-joints, nor in the peritoneum, and the surface of the testes was white.

It is certain, then, that the pigmentation present in the F_2 recessive is not derived from the Bankiva, but must have come from the Silky, with the exception of that of the shanks, which occurs in both breeds. The next question is whether the recessives are all pigmented to a similar degree or whether some are destitute of pigmentation. Of such recessives, as seen in the list given in Part I. of this paper, there are three. One of these, No. 2 of the first brood, is still alive, being kept for breeding; so far as can be seen it is in the same condition as the one which was killed, as it shows the dark colour round the cloaca. The third, No. 4 of the first brood, also a male, was killed before I thought of looking for slight degrees of pigmentation, and therefore I can say nothing about it. In any case, we have the fact that one of the recessives is not pure, and therefore segregation is not complete and perfect in the gametes, as the Mendelian theory assumes. It may perhaps be suggested that slightly pigmented F_2 's are not recessives at all but heterozygotes, but this in the ordinary sense is impossible, because such birds do not occur in F_1 , in which all are heterozygotes. The only possible conclusion is that there is a tendency to segregation, but that the recessive character when it separates is no longer pure but is, at any rate in some individuals, modified by a slight degree of the opposite character; or if we adopt the presence and absence theory, we may say that the positive character is not entirely absent from the recessive individuals, but that distinct traces of it are present in them.

It is necessary now to make a detailed comparison between my experiment and those described by Bateson and Punnett in the paper to which reference has already been made. It will be seen that the inheritance of the pigmentation of the Silky in different crosses is exceedingly curious and complicated. Bateson

and Punnett crossed the Silky with specimens of a certain strain of Brown Leghorns in their possession. When the Silky hen was mated with the Brown Leghorn cock, the F_1 chicks, instead of being strongly pigmented as in the experiment I have described, were scarcely pigmented at all. It appears at first sight as if in the Silky \times Bankiva cross the pigmentation is dominant, while in the Silky-Leghorn the same character is recessive. Many of the F_1 chicks were reared, and in the adult state were almost indistinguishable in general appearance from pure unpigmented birds. Thus these F_1 birds were in appearance similar to the F_2 recessives described by me, though in constitution they were very different. I shall have to return to this point later. Careful examination of the F_1 's in Bateson and Punnett's experiment showed traces of pigmentation. These are described as sometimes patches on the wattles, skin, or shank; pigment was also often found in the periosteum of the femoro-tibial or tarso-metatarsal joints and frequently in the peritoneum. No mention is, however, made of pigmentation under the skin of the abdomen or on the wing-joints as in my F_2 recessives.

On the other hand, when the reciprocal cross was made, namely Silky cock with Brown Leghorn hen, the results were markedly different: the males were like those of the first cross, but the females were all deeply pigmented. It might be said that in this case the pigmentation was dominant in the females, recessive in the males, while when the Brown Leghorn was the male parent the pigmentation was recessive in both sexes. It is certainly remarkable to meet with such a sexual difference as this in a character which showed no signs before the crosses were made of being in any way sexual. No such sexual difference in the F_1 's has been found to occur in the cross with which I have experimented, or in crosses with the Silky described by other naturalists. In all other crosses known the F_1 's were deeply pigmented; and Bateson and Punnett point out that the almost complete absence of pigmentation in one or both sexes of the F_1 's in their case is related to the fact that the Brown Leghorns used by them had unpigmented shanks, while most breeds normally have pigment in the skin of the shanks, as in the *Gallus bankiva* described above.

Bateson and Punnett explain their results as due to the segregation of three pairs of hypothetical factors, namely, P, p, presence and absence of pigmentation, I, i, presence and absence of a factor which inhibits the development of the pigmentation, and F, f, presence and absence of femaleness. It may be noted here as an instance of the difficulty of keeping pace with Mendelian theories, that Bateson seems to have already abandoned his former theory of sex according to which maleness and femaleness were alternative to each other, for he now suggests that there may be another pair of characters, presence and absence of maleness. The inhibition factor I is supposed to

be homozygous in the male Brown Leghorn, heterozygous in the female, and the pigmentation factor to be homozygous in both sexes in the Silky. With regard to sex a further assumption is made, namely, that when an individual is heterozygous for both F and I, these two in segregation cannot pass into the same gamete, as there is a repulsion between them. The female, moreover, is considered to be always heterozygous for femaleness, while the male is homozygous for the absence of this factor. All these factors being assumed, whether any real meaning can be attached to them or not, their segregation according to the Mendelian theory is shown to produce results which agree approximately with those observed. But the approximation is not very close, there are many serious discrepancies between the expected and the actual results.

The next point to be considered is the nature of the inhibition factor in the Brown Leghorn. We have seen that the difference between this breed and others, such as *Gallus bankiva*, with regard to pigmentation, is that in the latter the skin of the shanks is pigmented, while in the Leghorn they are unpigmented. The difference, then, is in the degree of pigmentation. Why should the less degree of pigmentation be called an inhibition factor? It may be said it does not much matter what term is used so long as we agree as to the facts. But there is more here than a mere difference of terms. Bateson and Punnett assume that the inhibition factor forms a pair of factors segregating independently of the pigmentation factor and its absence. I see no justification for this. It seems more probable that the unpigmented character is alternative or allelomorphic to the pigmented, and in F_1 is dominant in the case of the Brown Leghorn because it is of a higher degree than in breeds with pigmented shanks. It is interesting to note that in Reptiles, which represent the ancestors of Birds, pigmentation in the skin and internal connective tissue is of general occurrence. It would seem, then, that in birds generally the pigment was transferred to the feathers and disappeared from the skin and interior of the body, but remained in the skin of the shanks, which is still, excepting those few species and breeds which have feathered legs, in the reptilian condition covered with epidermic scales. In the Brown Leghorn fowl this last remnant of the internal pigmentation has disappeared. But there is no evidence of a distinct factor inhibiting the development of pigment. There is no more reason for assuming the existence of such a factor in a bird with unpigmented shanks than in one in which the shanks, but not the rest of the body, are pigmented. In the latter case Bateson and Punnett admit that the unpigmented condition is recessive to the pigmentation of the Silky, and it is obviously more reasonable and more scientific to regard the condition of the Brown Leghorn as merely a higher degree of the unpigmented character. Such a higher degree would naturally imply that there is a

stronger hereditary tendency in the Brown Leghorn to the absence of pigmentation, and therefore it is not surprising that this character should be dominant in the cross with the Silky. It seems to me, then, more probable that the unpigmented character in Bateson and Punnett's experiments is directly alternative or allelomorphic to the pigmented; and I shall endeavour to show that their results can be as well, if not better, explained on this hypothesis as on their own. It will be evident from this paper that I am far from denying the occurrence of segregation, which is an obvious fact, although my own results show that it is not necessarily absolute or complete. It is further evident that a sexual difference could not appear in the F_1 's if there were not already some sexual difference in one or both of the two breeds crossed. The pigmentation tends to appear in the female sex more than in the male: this not only occurs in the F_1 's of the cross Silky $\sigma \times$ Brown Leghorn φ , but a similar tendency is seen, according to Bateson and Punnett, in the shanks of other breeds. It is not, then, an unreasonable hypothesis that the female Brown Leghorn has a greater tendency to the development of pigmentation, or that the hereditary tendency towards the unpigmented character is weaker in this sex and therefore not dominant. We may also assume that when fertilisation takes place, whether we regard femaleness as segregated from maleness or each of them as alternatively dominant, the tendency to pigmentation accompanies the female character. To express these assumptions in Mendelian fashion, we may write W for the unpigmented character which is dominant, and Wp for the weaker unpigmented character, retaining P for the pigmentation of the Silky. Then, instead of the complicated formulæ of Bateson and Punnett we should have the two reciprocal crosses expressed as follows:—

(A.) Brown Leghorn $\sigma \times$ Silky φ .			
	WW σ		PP φ .
Gametes	W + W		P σ + P φ .
F_1	WP σ	+	WP φ .
(B.) Silky $\sigma \times$ Brown Leghorn φ .			
	PP σ		WWp φ .
Gametes	P + P		W σ + Wp φ .
F_1	WP σ	+	WP P φ .

The above formulæ are not to be taken as implying that sex is determined entirely by the female, or that either sex does not contain the other in a latent condition, but merely that, as half the ova in fertilisation must actually give rise to females, the tendency to pigmentation passes only into these females.

We have next to see how this works out for the F_2 's. According to Bateson and Punnett's formulæ, the F_2 's from cross A are for the males 6 slightly pigmented to 2 unpigmented,

for the females 3 slightly pigmented, 3 fully pigmented, and 2 unpigmented. According to my hypothesis the results would be as follows:—

F ₁	WP ♂	×	WP ♀.
Gametes	W + P		W + P.
F ₂	WW + 2WP + PP.		

That is 1 unpigmented, 2 slightly pigmented, and 1 fully pigmented in both males and females.

Bateson and Punnett point out that according to their formulæ no fully pigmented males would be expected from this mating, while as a matter of fact a considerable proportion of fully pigmented males actually occurred, namely 12 out of a total number of 75. They regard these as of the constitution ffPPII or ffPPIi, and suppose that in the presence of a double dose of the pigmentation factor the effects of the inhibitor are in considerable measure overcome, in corroboration of which view they found that these specimens became less fully pigmented when adult. But here they have made a mistake in reading their own formulæ, for the combination PP occurs only once among the males (namely ffPPIi, fig. 4, p. 190 of the paper), and therefore the expectation on their own interpretation would be 1 in 8, not 1 in 4 as they assume. The actual numbers are:—

	Males.			Females.		
	<i>Full.</i> 12	<i>Some.</i> 42	<i>None.</i> 21	<i>Full.</i> 28	<i>Some.</i> 28	<i>None.</i> 13
Correct expectation acc. to B. & P. } Expectation acc. to my hypothesis. }	9·4	46·8	18·75	26	26	17
	18·75	37·5	18·75	17·25	34·5	17·25

It will be seen that the numbers obtained by experiment of fully pigmented males are too large for Bateson and Punnett's hypothesis and too small for mine, while it must be admitted that the numbers of females agree more closely with their assumptions than with mine. If we add together the numbers for the two sexes we have:—

<i>Full.</i>	<i>Some.</i>	<i>None.</i>
40	70	34,

which is a close approximation to the expectation on my hypothesis,

36 72 36.

The differences, therefore, between the actual results and the

expectation on my hypothesis are an excess of fully pigmented females and of partially pigmented and unpigmented males, with a deficiency of fully pigmented males. These differences would be explained if segregation were, as I have shown it to be in my experiment, incomplete, and at the same time pigmentation tended to develop more in the females. Thus in the females the WW's would be partially contaminated by P, and some of them would be partially pigmented instead of unpigmented, while some of the WP's would appear as fully pigmented instead of partially so. In the males, on the other hand, the PP's would be affected by W, and this would reduce the number of fully pigmented in that sex and increase the number of partially pigmented.

We have now to consider the F_2 generation from the mating B in which the Silky is the male and the Brown Leghorn the female. According to the formula of Bateson and Punnett the expectation is 3 fully pigmented, 3 partially pigmented, and 2 unpigmented in each sex. This expectation is fairly well fulfilled in the males, but in the females there is a great excess of fully pigmented over the partially pigmented: the former are nearly half as many again as the latter, and this the authors call a slight excess. The complete numbers are:—

	Males.			Females.		
	<i>Full.</i>	<i>Some.</i>	<i>None.</i>	<i>Full.</i>	<i>Some.</i>	<i>None.</i>
	56	55	34	74	55	38
Expectation	52.5	52.5	35	62.5	62.5	42

According to my hypothesis the F_1 's are

WP ♂, Wp P ♀,

and the gametes

W + P, Wp + P.

The zygotes therefore will be

W Wp, W P, Wp P, P P.

The first and last of these are the same as those which occurred in the original parents, while the second and third are the zygotes of the male and female F_1 's. This is the ordinary result of Mendelian segregation in the F_2 : one pure dominant, one pure recessive, and two heterozygotes. The difficulty is to decide what will be the distribution of the sexes among these zygotes. If we suppose that Wp is always coupled with the female character, then all the W Wp's and Wp P's will be females, and all the rest males. But this would make not only the W P's but also all the P P's male, and it seems improbable that the pure Silky character in the F_2 should be confined to one sex. We may conclude that the P P's will be of both sexes and likewise the W Wp's. We may assume that the heterozygotes W P and Wp P will be in the

same condition as in the F_1 , the former all males, the latter all females. Thus we shall have for the males

W Wp, 2 W P, P P,

and for the females

W Wp, 2 Wp P, P P.

In the males, therefore, the ratio should be one unpigmented, two partially pigmented, and one fully pigmented. It must be admitted that this does not agree with the actual results obtained by Bateson and Punnett; but if segregation is not always complete, some of the W P's might appear in F_2 as fully pigmented and would then be added to the P P's, and the number of partially pigmented and fully pigmented might be equal.

In the females on my hypothesis there should be one unpigmented to three fully pigmented, and none partially pigmented. This again does not agree with the actual figures; but if segregation is incomplete, the P in the Wp P may be affected by the W, and so a certain number of females might appear as partially pigmented. In any case there is actually a great excess of fully pigmented females over the partially pigmented, whereas according to Bateson and Punnett the numbers should be equal.

There is another point in Bateson and Punnett's figures of the F_2 's from this cross which may be of great importance, although it is not noticed by the authors themselves. According to their hypothesis the total numbers of the sexes should be equal, whereas they are actually 140 males to 167 females. Thus there is not only an excess of fully pigmented females over the partially pigmented, but a large excess, more than 19 per cent., of females over males. This excess occurs in almost every family, and it seems improbable that it should be accidental. In the F_2 's from the reciprocal cross Leghorn ♂ × Silky ♀, on the other hand, there is an excess of males, 75 to 69 females. It would appear that the Leghorn was not only dominant as to character, but prepotent as to sex. I cannot attempt to explain this, but it is not in accordance with Mendelian theory.

In any case we are justified in saying that the actual results obtained by Bateson and Punnett in the F_2 generation do not agree in either of the reciprocal crosses with their assumptions, and that there is nothing in their results to prove that imperfect segregation may not occur in the cross of Silky with Brown Leghorn. It would scarcely be profitable to compare in detail the results of all the other matings recorded by Bateson and Punnett with those which would be expected on my hypothesis; the comparisons would be similar to those already given as examples. It is sufficient to point out that all their explanations are founded on the assumption that the pigmentation of the Silky is inherited as an indivisible unit, and that the result of my experiment shows that this assumption is contrary to fact.

In view of the subdivision of the pigmentation character proved by my results, the remarks of Bateson and Punnett on p. 201 of their paper are somewhat curious. They state that the F_1 birds, either of both sexes or of the male sex only, according to the mating, in respect of the intensity of their pigmentation might belong to either of their three classes, slight, some, or moderate, and that their experience has been that these classes grade very much into one another. Further on they remark that it would be possible to choose birds of the F_2 generation from Silky ♀ × Brown Leghorn ♂, and to arrange them in a series exhibiting continuous gradation from full pigmentation to none at all. "Yet we now know," they assert, "that such a series is due to the interaction of three definite factors, inclusive of the sex factor, and that the continuity of variation manifested is in reality founded upon a discontinuous basis." It seems to me that this is a misuse of words: we know nothing of the kind. What we know is the continuous gradation; and even apart from the results of my experiment, the discontinuous basis to which the authors refer is purely hypothetical. Moreover, one cannot help asking, in the light of the above quoted remarks, what value is to be attached to the distinction of the three degrees of pigmentation, full, some, and none, on the numbers placed under which degrees the validity of the factors assumed by the authors entirely depends.

In view of the failure of complete segregation in the two characters dealt with in this and the preceding paper, it is natural to consider whether any of the other characters present in the two forms crossed also fail to segregate. This point is more difficult to decide in the other characters. There could be no doubt that the white plumage and the unpigmented skin were recessive with a trace of the dominant character, but in other characters any condition short of complete absence might possibly belong to the heterozygote.

The double hallux. This character obviously does not behave in the normal Mendelian fashion. In F_1 the double hallux is dominant but not completely so: in my F_1 cock both feet were normal, in the hen both feet had the double hallux. In F_2 there are nine normals to one with double hallux, but no intermediates.

Feathering of legs. There appear in the F_2 's to be two homozygous dominants, six heterozygous, and two recessives. If this is the correct interpretation, one of the recessives contained a trace of the dominant character, the degree of feathering being infinitesimal, only a few very minute feathers between the large scales. I am inclined to think that the only specimen recorded as having quite clean legs had really a trace of the character, for although no actual feathers were visible, the lower edges of the scales showed a slight ridge.

Crest. There are two specimens, Nos. 1 and 7, one cock and one hen, with no trace of crest and the rose comb pointed behind. These seem to be pure recessives showing complete segregation.

But there are also two, Nos. 2 and 5, in which the crest is very slight, less than in the F_1 . No decided conclusions can be drawn in this case.

Comb. I have not yet observed any intermediates between rose comb and single.

Silky Plumage. I have not yet observed incomplete segregation in this character.

Many cases in which the results of crossing experiments are not completely in accordance with the Mendelian theory are mentioned by Bateson in his 'Mendel's Principles of Heredity' (1909), among them being the double hallux, the leg-feathering, and the crest of fowls.

In the light of the facts which I have recorded, the doctrine known as Mendelism cannot be said to be based on sufficient evidence to justify the notorious dogmatism of its supporters. Mendelians assume that heredity is the transmission of unit characters, which may sometimes combine to form a new character which is transmitted as a whole, but that the units cannot be subdivided. If subdivision occurs it is assumed to be due to the fact that a supposed unit was really compound; if, however, the process of segregation is at least in some cases not complete, but each character after a cross is mingled with some fraction of the opposite character, the assumption of units and all that is founded upon it falls to the ground. It is possible that segregation is only incomplete between characters which differ from one another in degree and not in kind, for example between pigmentation and absence of pigmentation in fowls. But if the doctrine now generally adopted by Mendelians of presence and absence is valid, it is difficult to see how this difference could exist. Hitherto, Mendelian experiments have been too exclusively carried out on the assumption of indivisible characters, whether real or imaginary, and the object kept in view has been to find, or invent, factors whose complete segregation would agree with the observed results. There is a promising field for research in the investigation of the divisibility of real characters.

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18. Studies on Pearl-Oysters and Pearls.—I. The Structure of the Shell and Pearls of the Ceylon Pearl-Oyster (*Margaritifera vulgaris* Schumacher): with an Examination of the Cestode Theory of Pearl-Production. By H. LYSTER JAMESON, M.A., D.Sc., Ph.D., F.Z.S.

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(1) INTRODUCTION.

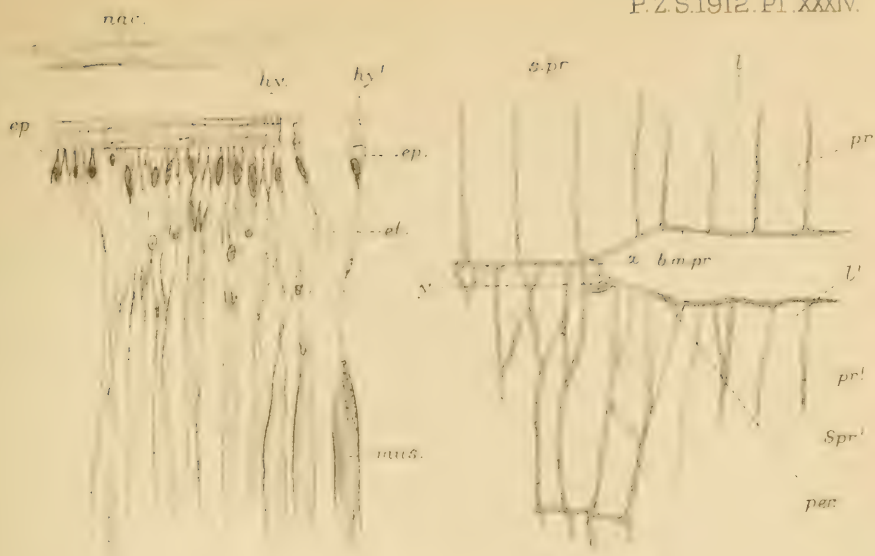
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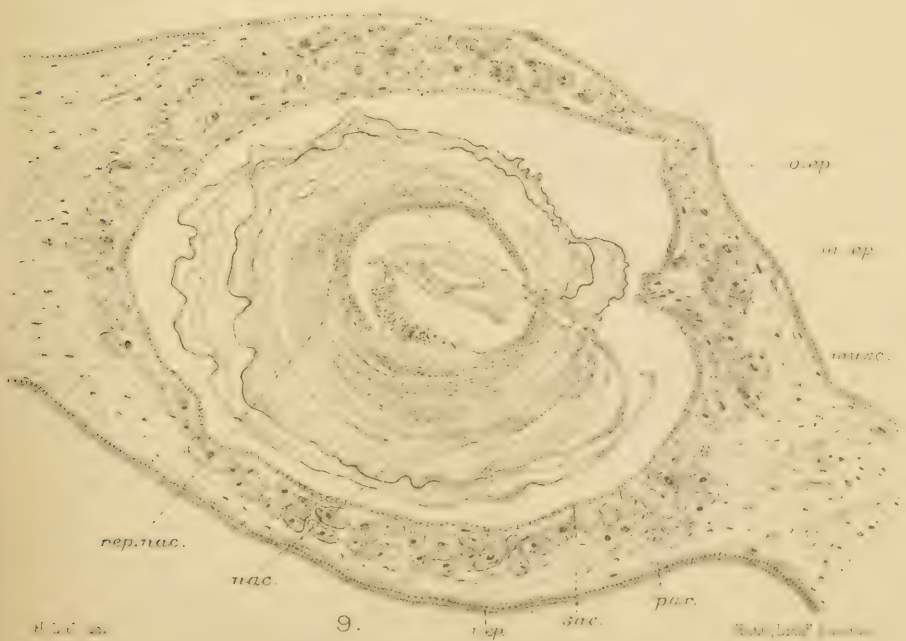
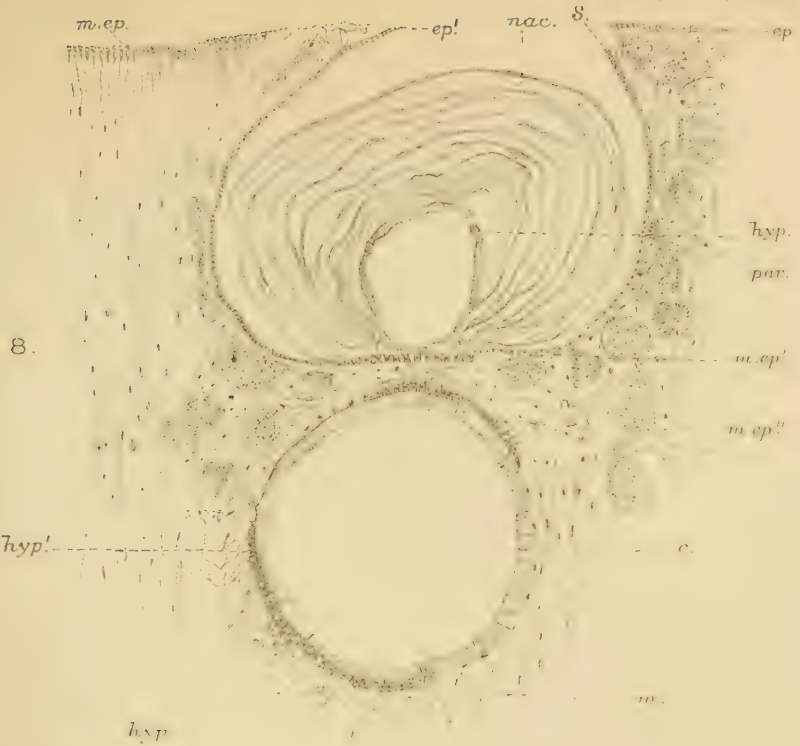
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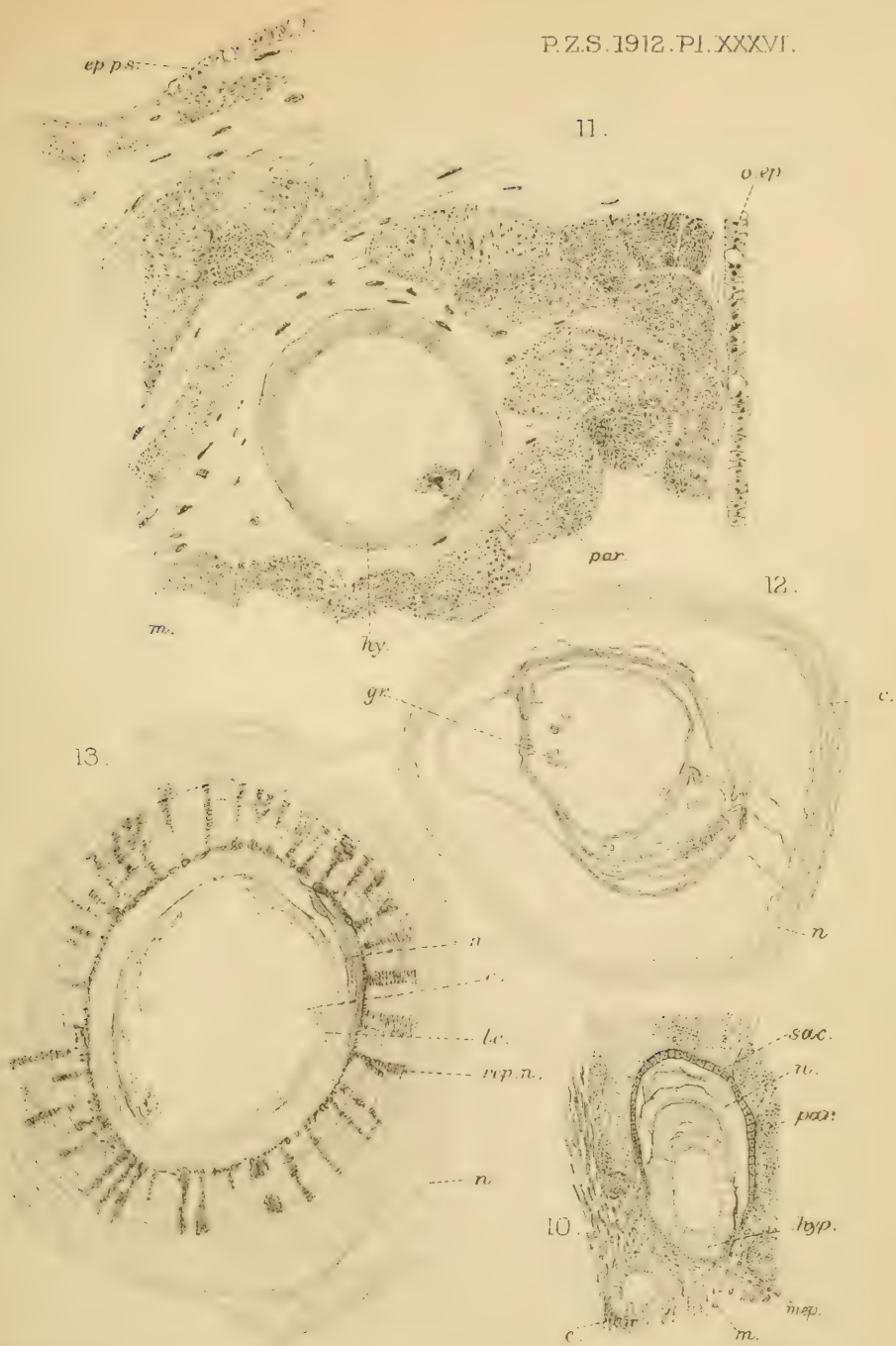
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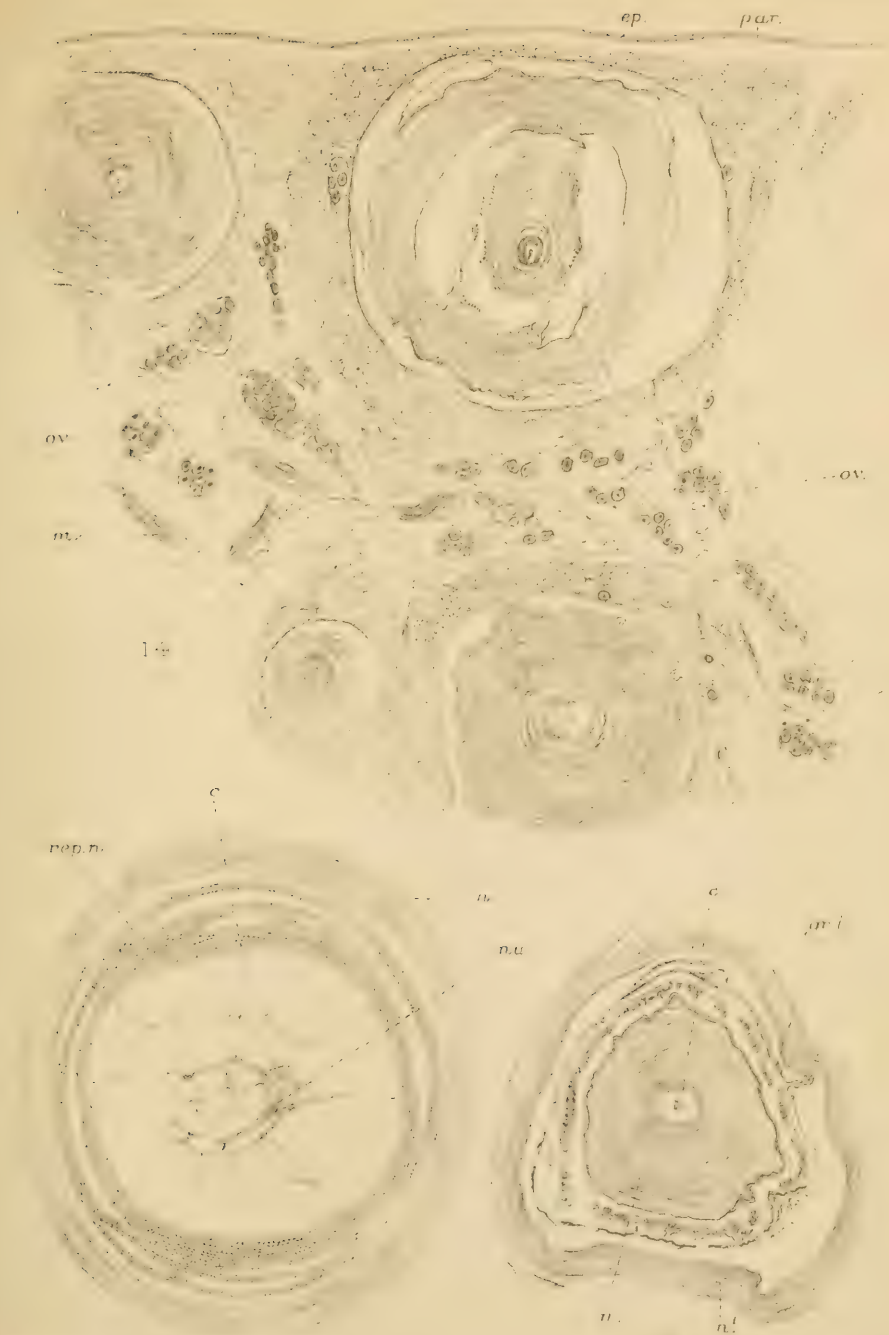
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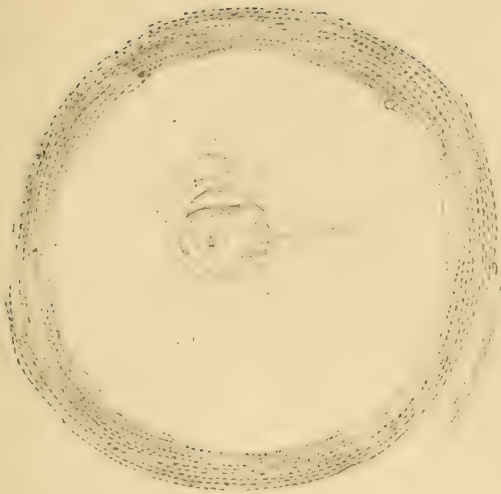
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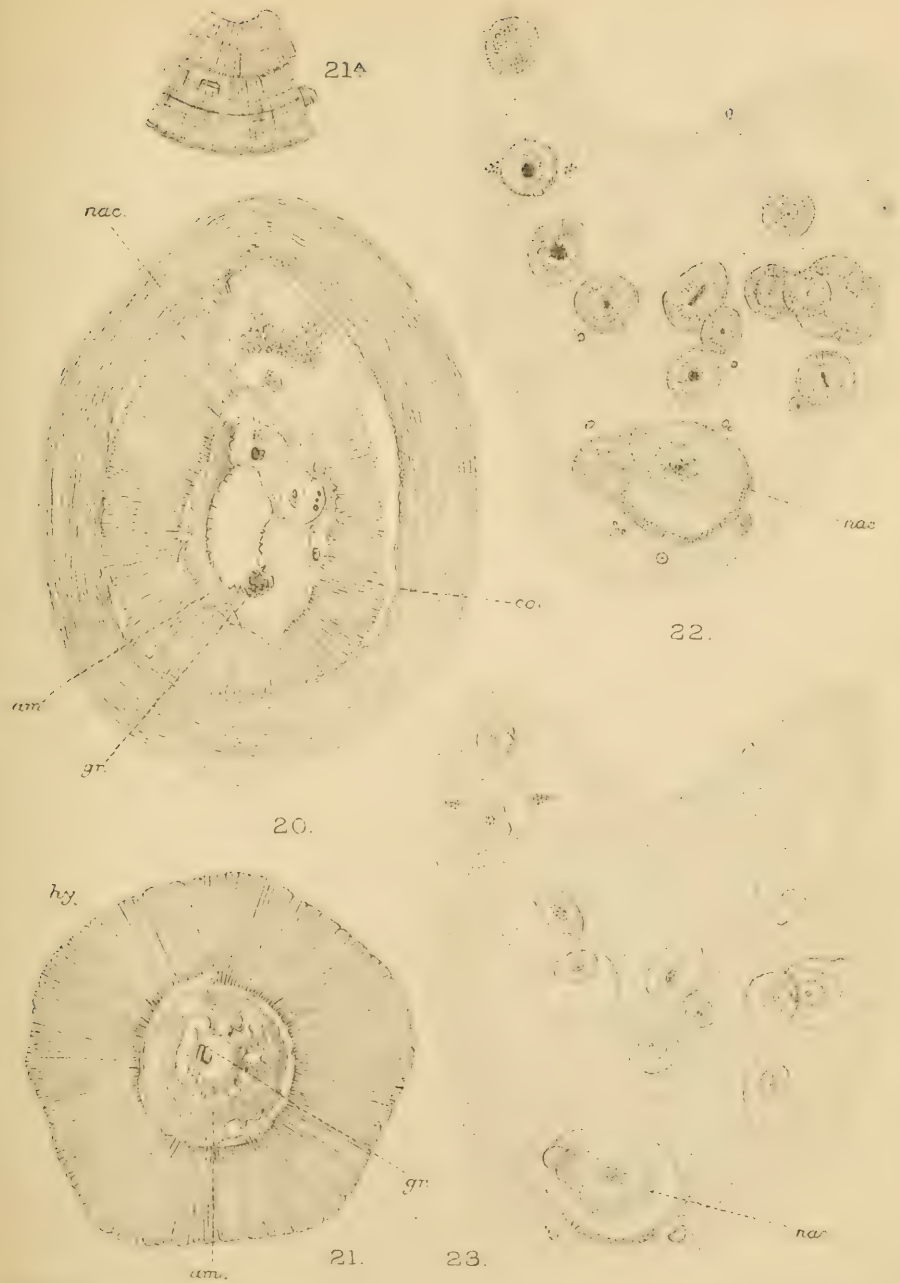
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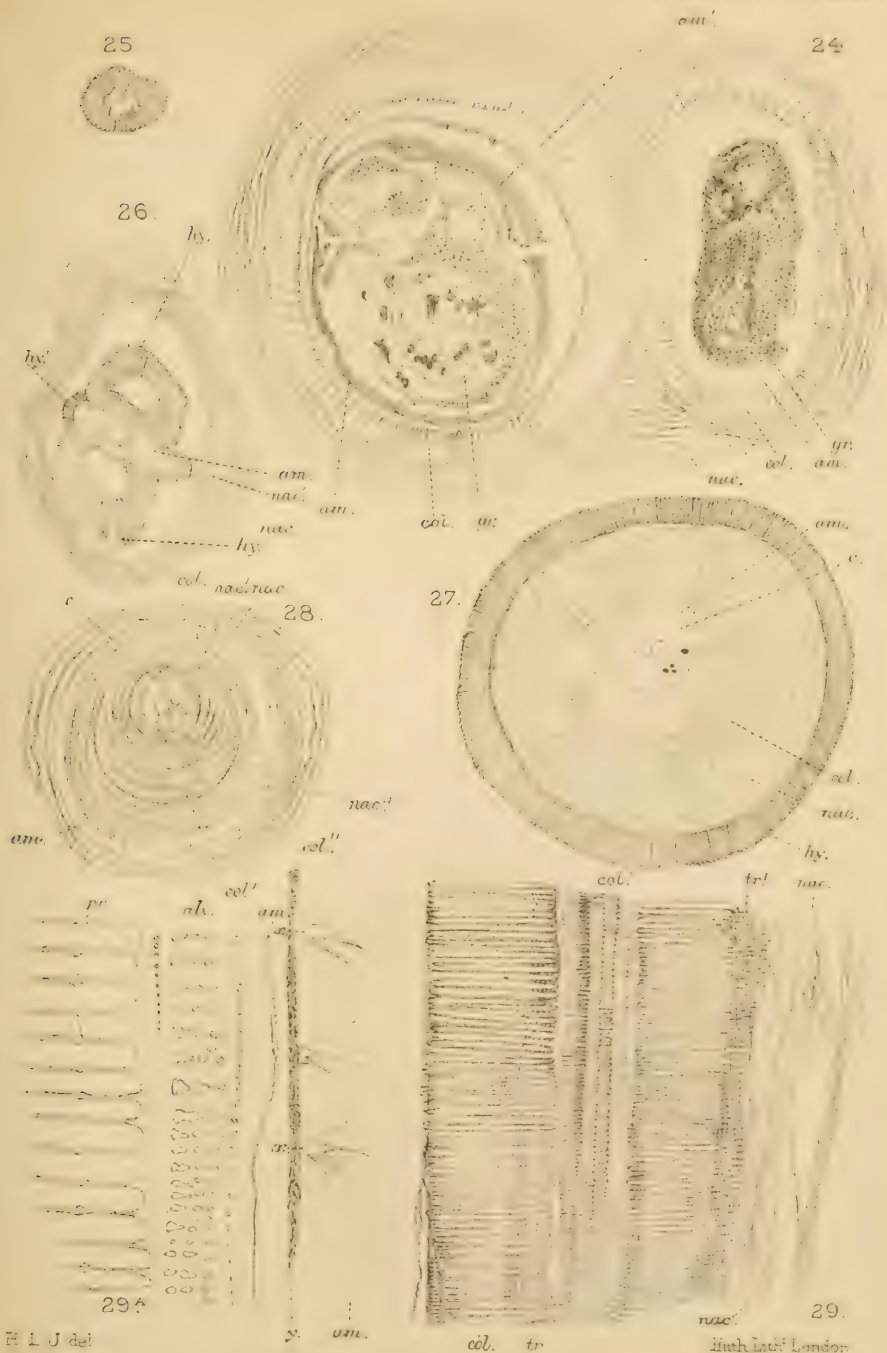
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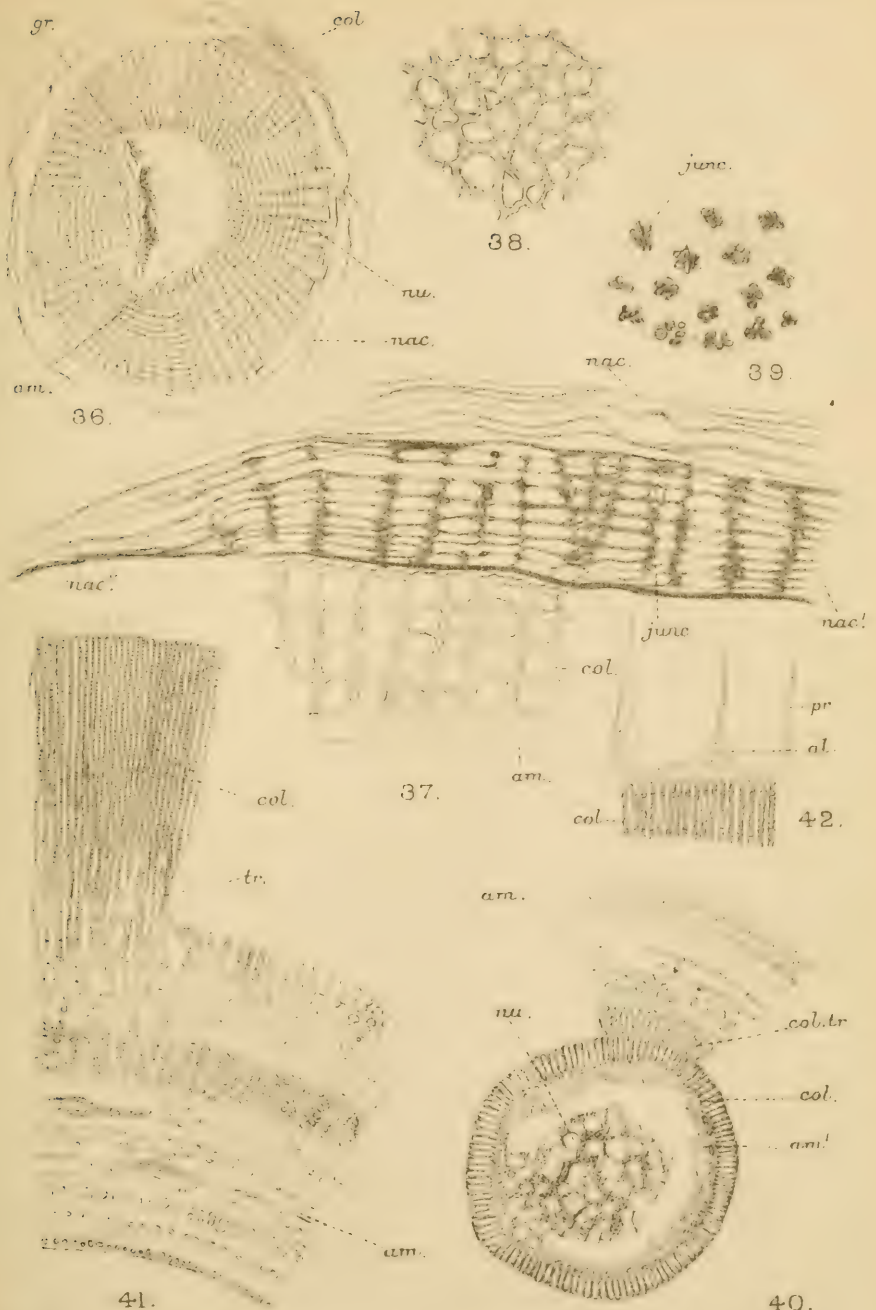
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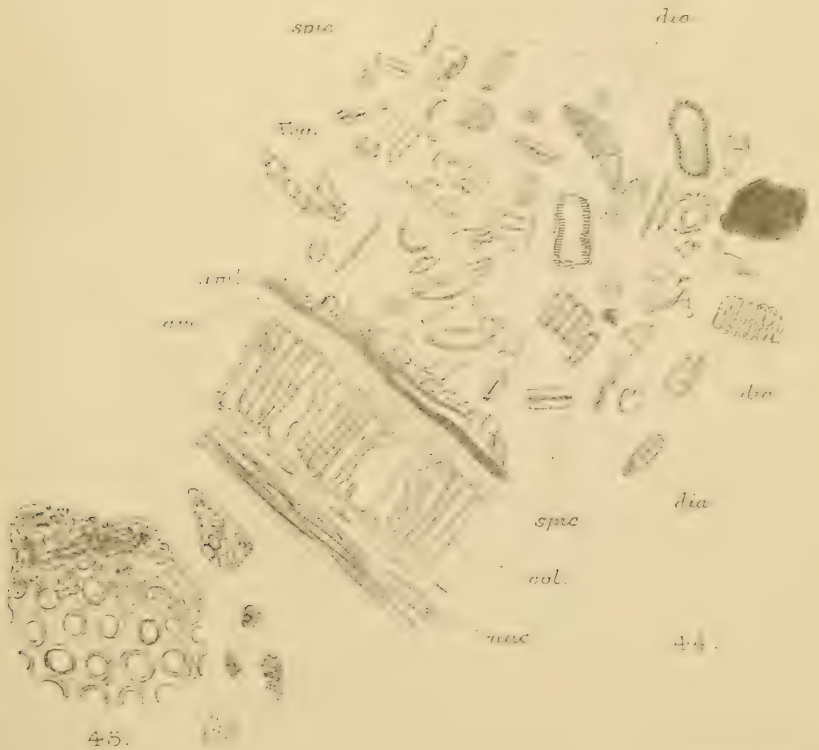
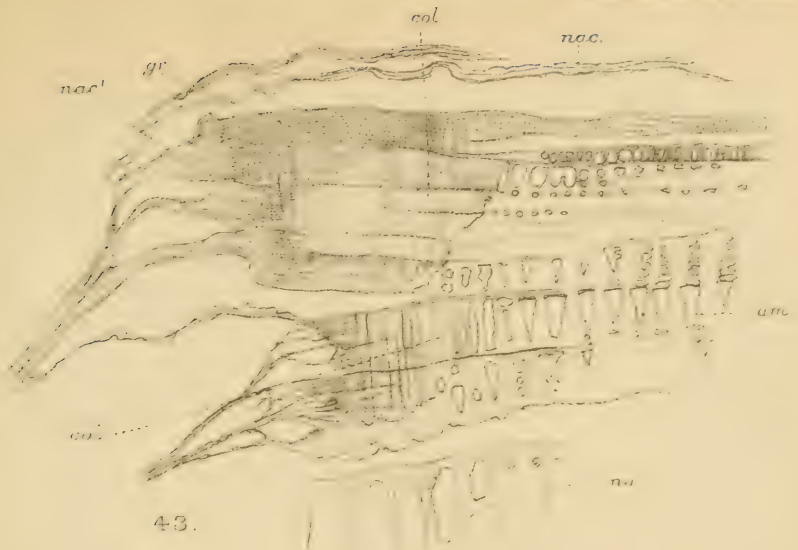
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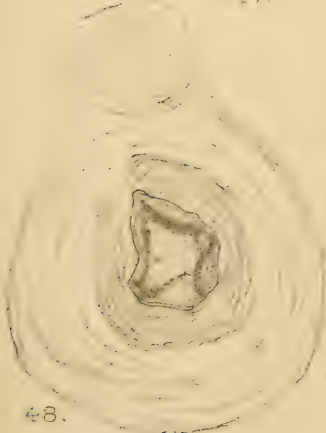
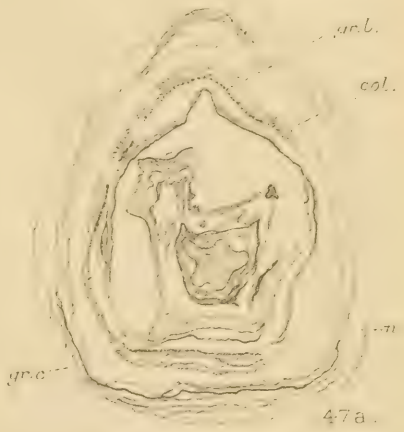
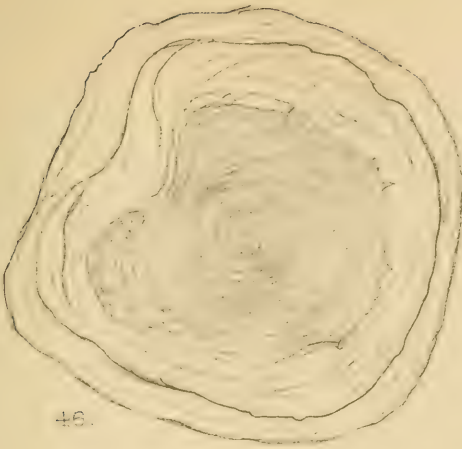
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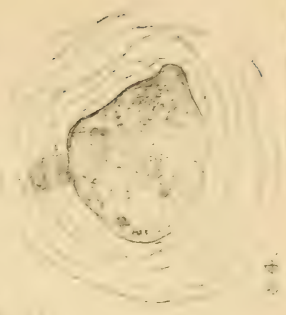
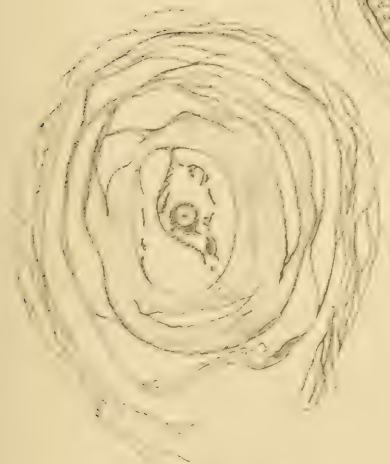
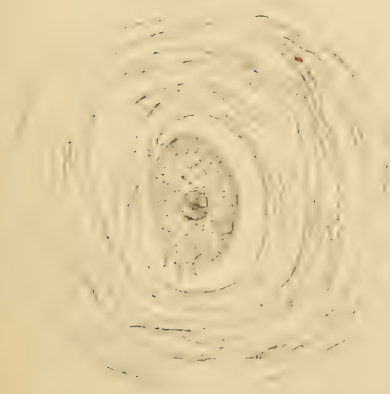
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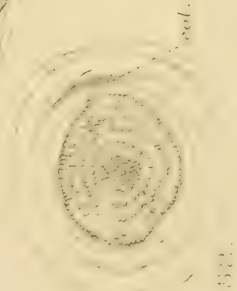
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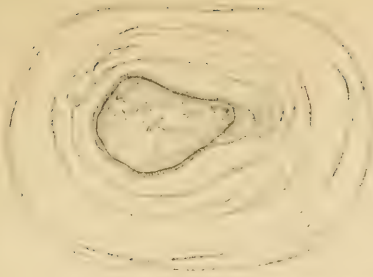




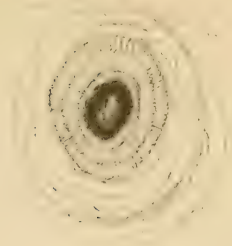
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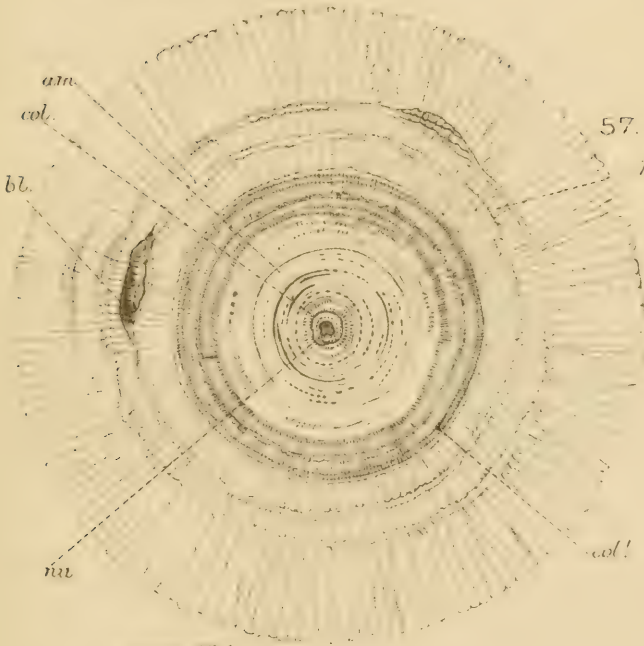
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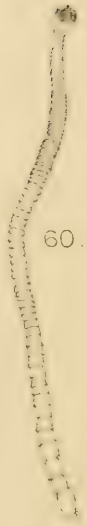
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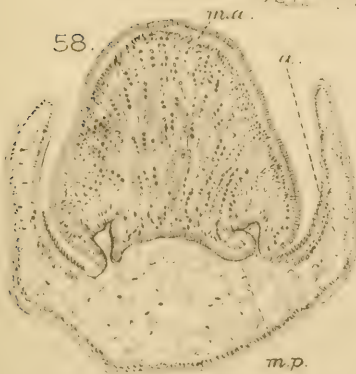
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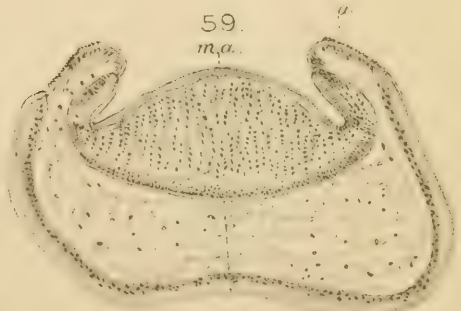
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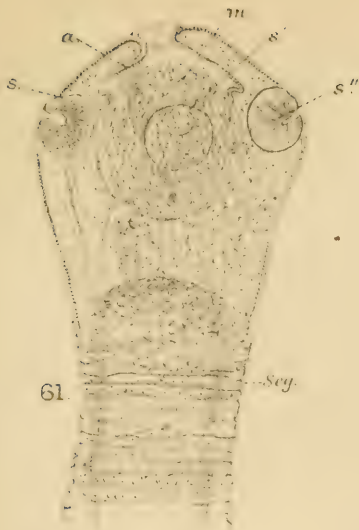


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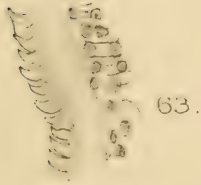
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on the Pearl-Oyster fisheries of the Gulf of Manaar (16) I was in South Africa, and material for the examination of some of his conclusions, which I was unable to harmonise with my own observations made prior to my departure from England, was not available.

Since my return I have made use of all available material—which is somewhat scanty; and while it is insufficient to enable me to propound, at the present moment, a working hypothesis as to the true cause or causes of the formation of Ceylon pearls, I think I have been able to show that the Cestode theory enunciated by Herdman, which has formed the basis of the somewhat meagre experiments which have been prosecuted in Ceylon since his return to England, and which even seems to have led to definite regulations elsewhere*, rests on quite insufficient evidence, and that, if the problem of the cause of Pearl-Production in *Margaritifera vulgaris* is to be solved, and a scheme for increasing the productivity of the Oysters evolved, a fresh start will have to be made.

The work that still remains to be done will centre around the causes which lead to the development of the epidermal sacs in which all pearls are formed—fine pearls and seed-pearls, “muscle”-pearls and “cyst”-pearls (or, as I prefer to call them, “parenchyma”-pearls), and the mechanism which controls the secretion of concholin and the deposition therein of carbonate of lime. In fact, I am led back to the principles enunciated by me in 1902 (25), that the essential element in pearl-formation is the pearl-sac, and not the nucleus, and that it is by a study of the causes which lead to the development of the former that the problem of the origin of pearls is to be solved.

Some material for these further investigations has just reached me as I write this introduction, and more is promised, but, owing to the difficulties and delays which may occur, I now publish my researches on the structure of the shell, and of pearls and their pseudo-nuclei and nuclei, without attempting to deal with the origin of the pearl-sac.

I take this opportunity of expressing my thanks to the Ceylon Company of Pearl Fishers, Ltd., for purchasing, on my behalf, pearls in Colombo to be used in these investigations; to Professor Raphael Dubois, for pearls from *Margaritifera vulgaris* from the Mediterranean; to Prof. W. R. Dunstan, F.R.S., for allowing me to make use of material in the Imperial Institute; to Mr. J. Calcott Gaskin, Assistant Political Agent at Bahrein, Persian Gulf, for sending me, in 1903, a number of preserved specimens of the Lingah shell (*M. vulgaris*), some of which contained pearls;

* Rules for Lower Burma under the Burma Fisheries Act, 1905. Rules 61 and 67, which prohibited the capture of *Balistes* and *Trygon* in the Pearl Fishery districts, and required them, if accidentally caught, to be returned to the sea, appear to have been inspired by the Cestode theory. These rules were cancelled in 1909. It may be remarked that the Pearl-Oyster of Burma (the Mergui shell of commerce) is not the same species as the Ceylon Pearl-Oyster, *M. vulgaris* Schumacher, but is the great Mother-of-Pearl Oyster, *M. maxima* Jameson.

to Mr. E. Hopkins, of Hatton Garden, for specimens of Ceylon Pearls; to Professor W. A. Herdman, F.R.S., for specimens of Pearl-Oysters from Ceylon, and for allowing me to examine his preparations; to Mr. Max Mayer, of Hatton Garden, for specimens of pearls for my work; to H.H. the Jam Saheb of Nawanagar, for specimens of Pearl-Oysters from the Gulf of Kutch; to Prof. L. G. Seurat, for pearls from New Caledonia, Madagascar, and the Gambier Archipelago; to Mr. A. E. Shipley, F.R.S., for allowing me to examine and make use of his specimens of *Tylocephala* and allied genera of Cestodes from Ceylon fishes; to Mr. E. A. Smith, I.S.O., for permitting me to make use of material in the British Museum (Natural History), including specimens from Dr. Kelaart's collection; and to Mr. A. Van Noorden (of the firm M. Myers, Mother-of-Pearl Merchants) for specimens of Lingah and other shells.

After this paper was handed in I received a copy of Rubbel's paper (34 a) setting forth in greater detail the results already published by him (33 and 34). Herr Rubbel and I have arrived, working independently on widely different molluscs, at identical conclusions on several important points, such as the nature of Herdman's "calcospherules." Where practicable, I have interpolated references to his work in the text, and my only regret is that it is not possible to discuss his valuable work more fully in the present paper and to dwell at length on the many points where, adopting a slightly different terminology and interpretation of the phenomena, our respective works lead to the same conclusions.

(2) OUTLINE OF THE RECENT INVESTIGATIONS IN CEYLON.

In January 1902 Professor W. A. Herdman went to Ceylon, at the request of the Colonial Office (who availed themselves of his services on the recommendations of the Council of the Royal Society and of Professor Ray Lankester), to investigate the condition of the Pearl-Banks. Professor Herdman took with him as his assistant Mr. James Hornell, who remained in Ceylon to carry on the work after the former's return to England in April of the same year, and who collaborated in the preparation of Professor Herdman's reports. Professor Herdman's visit in 1902 gave him seventy-eight days in Ceylon, and was largely spent in an extensive biological and faunistic survey of the pearl-banks, carried out on two successive dredging-cruises, each of several weeks' duration; and he credits Mr. Hornell with the major part of the observations on Pearl-production (Royal Institution Lecture of March 27th, 1903) (14). Prof. Herdman himself always seems to have regarded the condition and welfare of the natural beds of oysters as a more important problem than the question of pearl-production (Report on the Ceylon Pearl Fisheries, Part I. p. 5, and Part V. p. 29; also Report of the Annual Meeting of the Ceylon Company of Pearl Fishers, Ltd.,

for 1908*). In fact, he contends on p. 30 of Part V. of his Report, and in his address to the Linnean Society on 24th May, 1906, that

“to reverse the popular saying, if we attend to the prosperity of the bed as a whole, the individual oysters may be left to take care of themselves, both in regard to health and pearl-production.”

In January 1904 Mr. Hornell was appointed Marine Biologist to the Government, to which post were subsequently added the administrative duties of Inspector of Pearl-Banks. While holding these Government appointments Mr. Hornell continued to collaborate with Prof. Herdman, though it is clear that the executive and administrative duties attached to his post interfered not a little with the more strictly scientific observations. Thus, in his Report on the Inspection of the Ceylon Pearl-Banks, November 1905, Mr. Hornell says (23), p. 6 :—

“The working out of this material must of necessity await the long deferred time when a pause shall occur in the field work in which I have been engaged for the past eighteen months, and which permits me no leisure for the correlation and marshalling of biological data.”

And, again, in Reports from the Ceylon Marine Biological Laboratory, No. 1, p. 23, 1905, he says :—

“The Marine Biologist should be given opportunity to further investigate the life of the spherical Cestode so abundant in the Pearl-Oyster, and which is the inducing agency in the formation of ‘cyst-pearls’ (‘fine pearls’). The problem is far from solution, and will entail much unpleasant and trying labour before a satisfactory conclusion can be hoped for.”

The observations of Prof. Herdman and Mr. Hornell on the spot were corrected and correlated by laboratory work in Liverpool, carried out by Prof. Herdman and his staff at the University, on the material sent home for investigation. Prof. Herdman has courteously allowed me to examine the slides made during these investigations, showing sections of Pearls *in situ* in the tissues, and of the Cestode larvæ which he associates with pearl-formation.

In March 1906 the Ceylon Company of Pearl Fishers, Ltd., was formed and the pearl-fisheries were leased to the Company by the Government, at a yearly rental of Rs. 310,000, the lease carrying the obligation to spend, in addition to the above rent, a sum of from Rs. 50,000 to Rs. 150,000 yearly “on the experimental or

* Financial Times, Dec. 19, 1908. Sir West Ridgeway, Chairman of the Company, on this occasion said that

“with regard to biological research, Prof. Herdman was of opinion that in the present condition of the Company’s pearl-banks accurate navigation, careful and exhaustive inspection of the ground, and wise administration are more important than the purely scientific side of the business.”

practical culture of the pearl-oyster and on the improvement of the pearl-banks" (50).

On the formation of the Company Mr. Hornell was transferred to its service as local General Manager, Prof. Herdman being made Scientific Adviser.

In April 1908 Prof. Herdman, at the request of the Company, paid another short visit to Ceylon, to enquire into the question of the inspection of the banks and other branches of the business. As a result of Prof. Herdman's inquiries, the post of General Manager was abolished, being merged in that of Managing Director, and Mr. Hornell resigned, being succeeded by Mr. T. Southwell, A.R.C.Sc. (Lond.), who since 1907 had been acting as Mr. Hornell's assistant, and previously to that had assisted Prof. Herdman in his laboratory at Liverpool in the preparation of the material sent home for investigation. Mr. Southwell was made Scientific Adviser, a post which he still holds. Professor Herdman continued to be retained in an advisory capacity. Capt. J. Kerkham was appointed Superintendent of Fisheries*.

Besides the work of the Company's scientific employees, Dr. A. Willey, in his capacity as Marine Biologist to the Government (a post which he held along with the Directorship of the Ceylon Museum), has published some observations in the Ceylon Administrative reports and in '*Spolia Zeylanica*.'

Particulars of the work done, and of the conclusions arrived at, by these several naturalists will be given in the course of the paper.

In considering the incompleteness of the observations, despite the eight and a half years that have been devoted to the study of the Ceylon pearl-banks and the very large sums of money that have been expended, it must, of course, be borne in mind that for the last three or four years the banks are stated to have been practically bare of oysters†, and the prosecution of the investigations initiated by Prof. Herdman has thus been seriously hampered. But it is amazing that a Company whose prospects were so largely dependent on scientific work should have failed to set by an adequate stock of properly preserved material for scientific investigations and to establish at a suitable station a reserve of live oysters when the oysters were passing through their hands by the million. Had this been done, the barren years that have now come might have been devoted to the examination and amplification of Prof. Herdman's observations,

* Since the above was written the operations of the Company have ceased. It was announced in the '*Times*' of April 4th, 1912, that the lease had been terminated, a deposit of £10,000 together with the property of the Company being forfeited to the Government. An examination of the causes of the failure of this short-lived Company, which started with a capital of £165,000, has lately been published by the present writer (26*a*).

† Not entirely; for it was possible to obtain 12,000 oysters in Feb. 1910 for Mr. Southwell's feeding experiment described in Part V. of the Ceylon Marine Biological Reports, p. 213, and no less than 35,000 oysters ranging from 8 months to 2½ years old were obtained for the experiment described in Part IV. of the same publication, p. 169. Mr. Southwell, in a paper published in May 1911 (42), says: "The only bed which now exists is confined to an inshore area, and the oysters found thereon only rarely contain the pearl-inducing parasite."

which of necessity were somewhat cursory and superficial. The result of this lack of foresight has been that the energy that ought to have been concentrated on an intensive study of the pearl-oyster and the mechanism of pearl-formation appears to have been largely dissipated on general faunistic work, such as the description of new species of crabs and tapeworms, matters which, valuable as they are from the purely scientific standpoint, have only a secondary bearing on the problem of increasing and rendering more reliable the supply of pearl-oysters and pearls.

(3) PROFESSOR HERDMAN'S CONCLUSIONS ON PEARL-FORMATION.

Professor Herdman distinguishes several causes of pearl-formation, though only two of these are regarded as of sufficient frequency to have economic importance, viz. Cestodes, causing the majority of "cyst-pearls," and "calcospherules," causing "muscle-pearls." I will pass over the pearly excrescences or "blisters" on the inside of the shell, due to the irritation of boring animals or intruding particles of foreign matter, as these should be kept in a category entirely distinct from true pearls. The latter term, following my paper published in 1902 (25), I shall confine strictly to bodies developed independently of the shell, which are not in any way continuous with the shell, except where, owing to the rupture or absorption of the intervening tissues, they may become secondarily covered over with nacre continuous with the lining of the shell. When this happens to a pearl it becomes an "attached pearl," a body quite other than a blister. Attached pearls are valued for the true pearl that can often be dissected out of them, whereas blisters are used as substitutes for pearls where the imperfect side can be concealed in the setting, *e. g.* in cheap jewellery, rings, pins, brooches, etc. Prof. Herdman (Report I. p. 10) apparently applies the name "ampullar pearls" to blisters, that is to say to bodies "which are not formed within closed epithelial sacs like the others, but lie in pockets or ampullæ of the epidermis," and on p. 146 of the same part speaks of blisters as "pearls of an inferior quality," but I cannot help feeling that, in scientific terminology at least, it is undesirable to apply the term "pearl" to these bodies at all.

Professor Herdman recognises the following causes of pearl-formation in the Ceylon pearl-oyster:—

(i.) *Grains of Sand and other Foreign Particles.*

These, in the experience of Professor Herdman and Mr. Hornell, only form the nuclei of pearls under exceptional circumstances. In the whole of their observations they have only records of three such cases out of hundreds of pearls examined (Report V. pp. 4 & 127). They say (V. p. 28):—

"Probably it is only when the shell is injured, *e. g.*, by the breaking of the 'ears,' thus enabling sand to get into the interior, that such particles supply the irritation that gives

rise to pearl-formation. The ectoderm, in such cases, would probably also be damaged, and cells may be carried in with the inorganic particles."

As shown below, the presence of grains of sand and other foreign particles in the nuclei of some Ceylon pearls has been confirmed by the present writer.

(ii.) *Boring Animals.*

While recognising that pearly excrescences or "blisters" are mainly due to borers such as *Leucodore* and *Clione*, Herdman and Hornell say (Report V. p. 28) that

"in exceptional cases a free pearl may be formed in this way."

No specific instances, however, are cited, nor is any explanation suggested as to what would be the mechanism in such cases.

(iii.) *Parasites other than Cestodes.*

In his lecture at the Royal Institution, referred to above, Prof. Herdman said:

"We shall I think be able to show in our final report that Cestodes, Trematodes and Nematodes are all concerned in pearl-formation."

At the same time he recognised the "larval Cestode of the *Tetrarhynchus* form" as the most important cause. Again, in the Report (V. p. 29), Herdman and Hornell say:

"A fuller experience is causing us to incline to the view that various parasites may act as pearl nuclei, even in the same mollusc. Some pearls are certainly formed around intrusive Nematodes. We have a complete cyst pearl, free and unattached, of which the nucleus is a coiled *Cheiracanthus uncinatus*, on which the pearl deposit is not sufficiently thick and opaque to obscure the coils so as to render identification difficult."

This pearl does not appear to be in Prof. Herdman's collection.

(iv.) *Pearls without a Nucleus.*

Prof. Herdman points out that both in the case of the Ceylon Pearl-Oyster and *Mytilus* some pearls have no trace of a nucleus (Report V. p. 18). He figures one such pearl from *Mytilus*, magnified 100 times. The existence of pearls without nuclei was recorded by Harley (11) in 1889. The observations set out below show that in the Ceylon Pearl-Oyster, both in muscle-pearls and in a great number of parenchyma-pearls, the presence of a nucleus of foreign origin is quite unnecessary, and point to the conclusion that the origin of the pearl-sac is usually due to stimulation other than that caused mechanically by such bodies.

So far as *Mytilus* is concerned, I attribute the conditions where

a nucleus is absent to two alternative causes. In the first case, the Trematode described in my paper on the Origin of Pearls in the P. Z. S. for 1902 (25) may migrate out of the sac, in which a pearl without any nucleus, or with a nucleus consisting of a few residual granules, may subsequently be formed. In the second case, in certain localities, *Mytilus edulis* produces pearls through an agency (which I am at present trying to investigate) other than Vermian. These pearls may have as nuclei either a few dark granules or nothing that can be detected without the use of much higher magnification than 100 diameters. One of them is shown at C in text-figure 33 (p. 277).

(v.) *Muscle-Pearls.*

The discovery of "muscle-pearls" was, I believe, first announced at the British Association Meeting in September 1903.

Under this name (Brit. Assoc. Report, Southport, 1903, p. 695) Prof. Herdman distinguishes pearls formed "around minute calcareous concretions, the 'calcospherules,' which are produced in the tissues and form centres of irritation." They occur "most abundantly in the muscular tissue near the insertions of the levator and pallial muscles." (Report, Part V. p. 27.) Herdman and Hornell say, speaking of muscle-pearls:

"it seems probable that these have been formed by the deposition of calcareous matter around a minute calculus in the tissues" "The Muscle pearls when present are usually abundant, and when examining under the microscope a young pearl of this kind, *in situ*, it is common to find a large number of minute calcareous depositions or calcospherules scattered in the neighbouring tissue. It is probable that the muscle pearls are formed around these microscopic calcospherules as centres of irritation, and as these [?their] positions are invariably in our experience close to the surface of the muscle or the mantle, there is no difficulty in understanding that there, if anywhere, ectoderm cells might migrate to the source of irritation and thus be responsible for the deposition of a pearl." (Report V. p. 27.)

Muscle-pearls are especially numerous in certain localities; Prof. Herdman instances (Report V. pp. 30-31) that they were particularly numerous on the S.E. Cheval Paar in 1902 and 1903, and

"that the vigorous and healthy oysters of the Eastern Cheval and Periya Paar Karai produce practically all the examples of this class of pearls,"

the numbers produced on other banks being insignificant.

Mr. Hornell, speaking of an examination of a number of pearls attached to the shell, states that "decalcification of the pearls attached to muscle-scars reveals no organic nuclei, whereas the [attached] pearls irregularly disposed have Cestode embryos as nuclei, exactly as 'fine' pearls have." (19, p. 12.)

Mr. Southwell (40, p. 194), referring to the calcospherules causing "muscle-pearls," says:

"The origin of the latter bodies is quite unknown, although it seems almost certain that they are depositions from the blood."

Again, in a later paper (42, p. 128), Mr. Southwell says:

"Other pearls are also found in the Oyster, but they have no organic nucleus. Such pearls are termed muscle or seed pearls. Their origin is obscure, but they are always found near the muscle insertions, and are believed to be formed round a calcospherule of excretory origin, or by the sheer of muscles moving in different planes."

In the first mentioned of the above papers (40), he goes on to say:

"Considerably more pearls are formed round calcospherules than round parasites, the ratio being about 13 to 1. They are therefore of considerable commercial importance."

Unfortunately, Mr. Southwell does not give the number or sources of the pearls on which this statement is based, although it is quite clear, from the observations of Prof. Herdman and Mr. Hornell, that "muscle-pearls" are characteristic of certain localities, and "cyst-pearls" of others, and that the ratio may vary greatly on different banks.

My own observations on "Muscle-pearls" and on the nature of the so-called "calcospherules" are given in a later part of this paper.

(vi.) *Cestode Larvæ.*

Of fine or "Orient" pearls Prof. Herdman and Mr. Hornell claimed that the most frequent nucleus is a Cestode larva. In their "Conclusions on Pearl-Formation" (Report V. p. 29) they maintain that their investigations have shown "that in *Margaritifera vulgaris*, at Ceylon, the production of the 'Orient' pearl is dependent upon Cestode infection and that the species mainly concerned is *Tetrarhynchus unionifactor*," and in the General Summary of their Ceylon Report (V. p. 127) they say:

"The majority of these fine pearls contain as their nuclei the more or less easily recognisable remains of certain Platyhelminthian parasites, which we identify as the larval condition of Cestodes belonging to the genus *Tetrarhynchus*."

It is stated several times that this supposed identification was made during Professor Herdman's second cruise in March 1902, but its elaboration must have been, in great part, the work of Mr. Hornell at a later date. The narrative of the Cruise (Report I. p. 70), published in 1903, states, in a paragraph apparently inserted between the records of March 6th and 7th:

"In the intervals of dredging and when moving from place to place, we were now continuously engaged in

examining the parasites of the pearl-oyster and their influence on pearl-formation. We also decalcified such pearls as were found. This work was continued as time permitted during the next few weeks, and also by Mr. Hornell after I left. We found various parasites, in the liver especially, some of which were Platyhelminthian and others Sporozoan in their nature, and some of which were enclosed in calcareous capsules. Mr. Hornell afterwards determined that these were *Tetrarhynchus* larvæ of Cestodes, and we have no doubt that they are in many cases the nucleus of the pearl, and the irritating cause of its formation."

Again, in the preface to Part II. of his Report, p. vi, dated July 1904, Prof. Herdman says :

"On the Cheval Paar, in March 1902, we satisfied ourselves that the 'Orient' pearl, free in the tissues of the pearl-oyster, is deposited around a cyst containing a Cestode larva, and preliminary notices to this effect were published in my Royal Institution Lecture of March 27, 1903, and at the Southport Meeting of the British Association in September 1903."

On p. 6 of Part V. of the Report (Pearl-Production), Herdman and Hornell say :

"One of the first facts that we were able to determine in connection with the Ceylon Pearl-Oyster, in the spring of 1902, was that the Orient pearl in the Gulf of Manaar is deposited around the young larva of a Cestode."

And on p. 15 :

"We found the Cestode larvæ in association with pearls in the tissues during our cruises in the 'Lady Havelock' in the Gulf of Manaar, in February and March, 1902. It was about March 6th (see Narrative, p. 70, in Part I.), when cutting up Oysters from the western part of the Cheval Paar, that we first became convinced that the opaque white globular larvæ we were finding encysted in the liver belonged to Cestode worms."

On the other hand, Shipley and Hornell, in their paper on the Parasites of the Pearl-Oyster (Herdman's Report, II.), seem to imply that at least the elaboration of these observations was carried out subsequently to Professor Herdman's departure from Ceylon. Thus, they say (p. 79) :

"These larvæ first attracted attention during the second cruise of the 'Lady Havelock,' on March 6th, 1902, when numbers of the early globular stage were dissected out from the livers of oysters dredged from the West Cheval Paar. Subsequently, during the investigation carried out at the Galle Biological Laboratory, a second and more advanced stage of a *Tetrarhynchus* larva was found in the same

material. Details of the morphology and histology were then worked out, and the relationship which the larvæ bear to pearl-formation was investigated."

Strange to say, Professor Herdman's Preliminary Report to the Government, dated July 1st, 1902 (13), makes absolutely no reference to the discovery in the previous March of this important aspect of the parasites of the Pearl-Oyster.

In the Preliminary Report referred to, Prof. Herdman says (p. 2):

"Samples of all the oysters obtained by us were examined for parasites and for any diseases or abnormal conditions, and although a considerable number of minute parasites, both Protozoan and Vermean, were found, still that is by no means unusual amongst molluscs, and we do not consider that we saw anything which gave evidence of any epidemic disease or widespread and injurious prevalence of parasites."

And again in the same Report (p. 4), in his summary of conclusions, the Professor says:

"A considerable number of parasites, both external and internal, both Protozoan and Vermean, were met with, but that is not unusual in molluscs, and *we do not regard it as affecting seriously the oyster population.*" (The italics are mine.)

In view of the last three quotations, if it were not for the very definite assertions in Part II. p. vi, and Part V. p. 6, of Professor Herdman's full report, quoted above, I should be almost inclined to think that, while the Cestode larvæ were no doubt discovered "in association with pearls" during Professor Herdman's cruise, the Cestode theory of Pearl-formation might have been evolved after Professor Herdman's return to England, and after the above-mentioned preliminary report had been submitted. In that case Mr. Hornell might well have been misled by the false analogy of the case of the Trematode origin of pearls in *Mytilus*, which was dealt with at length in my paper (25). This paper appeared in August 1902; that is to say shortly after the Professor's preliminary report of July 1st, 1902, containing no reference to the Cestode theory, was submitted. The view that my paper might have misled Mr. Hornell and Professor Herdman would also derive support from the fact that the real point of my paper had apparently been missed, viz. that it is not the presence of any parasite, but the *specific stimulation of a particular kind of parasite* that causes the growth of the pearl-sac. I consider this point is by far the most important contribution I have so far made to the subject, and I believe it will be the basis upon which a rational system of artificial pearl-production will ultimately be built.

The first announcement of Prof. Herdman's theory of Pearl-formation seems to have been made at a lecture delivered before the Royal Institution on March 27th, 1903, an abstract of which appeared in 'Nature' for April 30th of the same year (14).

(4) EXAMINATION OF THE CESTODE THEORY OF PEARL-PRODUCTION.

It is unfortunate that more figures of pearls containing as nuclei supposed Cestodes are not given in Prof. Herdman's account of Pearl-formation. The only figures that represent the nuclei of decalcified pearls examined entire* as transparent objects appear to be those on plate ii. in the Section on Pearl-Production in Part V. of the Report, figures 5 and 7, figure 6 representing a dead Cestode in a partially calcified cyst (not, however, a pearl). On p. 22 it is stated that these drawings, which are reproduced from Shipley and Hornell's article upon the parasites of the Pearl-Oyster in Part II. of the Report, are the work of Mr. Hornell, and it is not evident from the text that Prof. Herdman had ever seen the specimens from which they were made. Turning to these same figures on plate i. of the article by Shipley and Hornell on the parasites of the Pearl-Oyster (Part II. of the Report, figs. 5 (A) and 8 (B), (C), (D)), we find them described in the Explanation of the Plates as the nuclei of decalcified pearls; but the same figures are referred to in the text, p. 80, as representing the Cestode larva enveloped in its "tough elastic and fibrous capsule of spherical form, derived from the adjacent connective tissue cells."

It is, I think, hazardous to identify these figures as the remains of Cestode larvæ without examination of sections, and I cannot help feeling that each of these figures is capable of comparison with the non-Cestodian centres of pearls described by me below.

It is a remarkable fact that nowhere throughout the Report is there figured a *section* of a decalcified pearl showing the Cestode remains in the nucleus, and to this fact I may add my own observation that of all the pearls sectioned *in situ* by Prof. Herdman, numbering about 25 (not counting some minute clustered muscle-pearls), which he kindly sent me to examine, I could not find a single nucleus that I was able to accept as being a Cestode or other Vermian parasite. The characters of the nuclei in these preparations are described in the part of the paper which deals with my own researches.

The superficial resemblance of the pearl figured on plate ii. fig. 4 A, in Part II. (Parasites) of the Report, and again in Part V. (Pearl-Production), pl. i. fig. 5 *k*, *c*, *d*, & *e*, to the globular Cestode larvæ found in the Oyster is hardly enough to go upon. If such a pearl consisted of a parasite thinly coated with nacre it would probably be dark and valueless and not a "fine pearl," for the yellowish-brown dead tissue of the Cestode should be clearly visible through the nacreous coat. It is not stated whether this pearl was decalcified and sectioned to test whether the resemblance was more than "skin deep."

* These figures are referred to by Southwell (42), p. 128, as "figures of sections of decalcified pearls," but they are not described as such in the text; and they certainly appear to be no more than drawings of the centres of pearls examined as transparent objects.

With regard to the mechanism by which the Cestode is supposed to cause pearl-formation, Prof. Herdman is unable to contribute much. He seems to recognise that the particular conditions necessary to transform the Cestode into a pearl-nucleus are not by any means universally present, and that it is only, so to speak, under exceptional circumstances that the Cestode, which is very abundant in the Ceylon Pearl-Oyster, becomes the centre of a pearl. The larva is surrounded by a connective-tissue cyst, and has not been satisfactorily demonstrated in any instance with an epithelial "pearl-sac" (such as I described for the Pearl-inducing Trematode in *Mytilus*), though supposed proliferations of cells inside the connective-tissue cyst are figured in the Report (Part V. Pearl-Production, pl. iii. fig. 7). These, being inside a thick fibrous connective-tissue capsule, are difficult to accept as being equivalent to a pearl-sac, which I generally find to be surrounded by the spongy subepidermal parenchymatous tissue, except in the case of those parts of a "muscle-pearl" into which muscle-fibres are inserted. From my own observations I am rather inclined to regard these "cells" as granules excreted by the parasite itself, with possibly an admixture of wandering leucocytes. In any case, if this is an epithelial pearl-sac, what becomes of the thick fibrous cyst outside it, which is certainly not present around the pearls? Professor Herdman himself (see below) does not think the Cestodes enveloped in thick connective-tissue cysts are destined to become nuclei of pearls.

The supposed migration of ectoderm-cells into the wall of a pearl-sac already formed and already containing a pearl, as figured in Part V. (Pearl-Production), pl. i. figs. 18-20, seems to be a matter quite apart from the question of the primary origin of the pearl-sac.

On p. 23 of Part V. Prof. Herdman says:—

"It is quite evident from the examination of a large series of sections, such as we have worked through, that the majority of these encysted parasites do not become encased in pearls. Probably none of those in thick connective-tissue cysts are destined to form nuclei. They are awaiting their legitimate further development in the next host, after their sheltering mollusc has been devoured by a fish. In such cysts and around such parasites we find no epithelial sac, and, as a consequence, there can be no pearl. Whether or not it is the case that only dead parasites supply the stimulus necessary to induce pearl-formation, and whether, as Giard has suggested, the parasites may be infested and killed by a species of *Glugea*, so that that Sporozoan comes to be eventually responsible for the pearl, we are not prepared to say—we have found no fresh evidence in the Ceylon material bearing upon that point. It seems clear to us, however, that the epithelium is always associated with pearl-formation, and that in the absence of the epithelium only a thick-walled connective-tissue cyst is produced. If we adopt the view (see

below) that this epithelium is genetically related to the ectoderm, then a possible explanation of the difference in behaviour in the encysted condition would be that those larvæ that carried in ectodermal cells become covered (when dead or while still alive) by a pearl-sac and embedded in a pearl, while those that were free from ectoderm become surrounded by the connective-tissue cyst."

No satisfactory instance, however, is recorded of the Cestode parasite being observed surrounded by an epidermal sac.

Again in Part III. of the Report, p. 32, Professor Herdman, quoting a Report furnished to him by Mr. Hornell, says the abundance or otherwise of cyst-pearls "is connected with the factors which control the relative abundance of the pearl-inducing Cestode and those which conduce to its death during encystment in suitable localities within the tissues—problems as yet obscure"; while in Part V. (Pearl-Production), p. 15, he says "it is apparently very difficult indeed to hit upon a stage showing the commencement of the pearl-formation."

And again, in an address delivered at the Anniversary Meeting of the Linnean Society of London in 1906 (17), Prof. Herdman, speaking of his Ceylon work, says that it is probably only those Cestodes that are provided with an ectodermal covering forming a pearl-sac that become the nuclei of pearls. But, as stated above, such an ectodermal pearl-sac has not yet been found to occur around the parasite, and its occurrence is purely theoretical.

The investigations made subsequently to the publication of Prof. Herdman's Reports have added little to our knowledge of the subject. In 1905 Mr. Hornell published a Report on the *Placuna placenta* pearl-fishery of Lake Tampalakamam, dated June 15th, 1905 (21). In this he states (p. 5) that he dissolved two *Placuna* pearls (out of five in his possession) and found that "in each case the nucleus proved to be the dead remains of a minute Platyhelminthian larva of the same stage and species as that which forms the nucleus of cyst-pearls in *Margaritifera vulgaris*." Further study revealed the presence of Cestode larvæ in the dorsal portion of the visceral mass. He considers that these are identical in details of form and structure with those of *Margaritifera vulgaris*, but expresses some doubt as to their specific identity, and adds that if they prove distinct the *Placuna* parasite will need a fresh name. Mr. Hornell further observed that these larvæ multiply asexually by a process of endogenous budding, which he wrongly refers to as parthenogenesis.

Mr. Hornell then goes on to make the following extraordinary statement, which I quote as giving some indication of the confusion of ideas which existed as to the identity of the supposed pearl-producing larvæ even in 1905, *i. e.* nearly three and a half years after the beginning of the observations:—

"The discovery of a stage in the life-history of this parasite, which I am confident is homologous with the
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Redia-stage of a Trematode, confirms my original idea of it being a larval Trematode—an idea formed when first I saw it in March 1902” [*i.e.* the Cestode larva in *Margaritifera vulgaris*]. “Other facts point to the same conclusion, and I have now no doubt on the subject. The genus to which it belongs is still doubtful, but as it is inconvenient not to have a name whereby to make mention of it, I shall henceforth refer to it under the cognomen of *Distomum* (?) *margaritifactor*, n. sp., the specific name having reference to the fact that it is the inducing cause in the production of ‘fine’ pearls.”

Mr. Hornell anticipated that asexual reproduction would be found to occur in the Cestode parasites of *Margaritifera vulgaris* also, and this has since proved to be the case.

An expurgated edition of the above report was published in 1906 (22), which, however, bore the same date, June 15, 1905, as the Sessional Paper. In this the statements as to the supposed Trematode nature of the parasite were suppressed (though not formally withdrawn), the name “*Distomum margaritifactor*, n. sp.,” cancelled with a stroke, still figuring in the lithographed plate (Annexure II.).

As explained below (p. 345) I have been unable to confirm the presence of Cestodes in the centres of *Placuna* pearls from Ceylon, any more than I can find them in the pearls of *Margaritifera vulgaris*.

In 1907 Dr. A. Willey (48) confirmed and extended Mr. Hornell's observations on the endogenous reproduction of the *Placuna* Cestode.

Mr. Southwell discovered (39, p. 173) that endogenous asexual reproduction or budding, similar to that described by Hornell and Willey in the parasite of *Placuna* occurs occasionally in the Cestode parasites of the Pearl-Oyster. He only observed the occurrence twice, in November 1906 and January 1909—in each case a single endogen was found.

In 1903 the late Professor A. Giard (10) announced that M. L. G. Seurat believed that in the black-lipped Pearl-Oyster of the Gambier Archipelago (*Margaritifera margaritifera* var. *cumingii* Reeve) pearl-formation was due to the presence of a parasite, figures of which were given, and which Prof. Giard referred to a genus near to *Cyathophyllus* [*Cyathocephalus*?] Kessl. or *Acrobothrium* Olsson.

Subsequently Seurat found the adult of this worm in the Eagle Ray (*Aetobatis narinari* Euphr.) in the spiral intestine, and named it *Tylocephalum margaritifera* (36). The adult, which is figured by Seurat (37), is quite a minute worm, not exceeding 4 mm.

The scolex occurs in cysts, similar to those occurring in the Ceylon Pearl-Oyster, and multiple cysts (perhaps formed by budding of the larva as in the *Placuna* parasites) occur also. Seurat

states that these cysts which form around the parasites become the nuclei of pearls, and a decalcified pearl shows an organic nucleus in the centre surrounded by concentric layers of conchyolin, the whole having a diameter of about a millimetre, and the nucleus being a scolex .225 mm. long and easily recognisable as that of *Tylocephalum*.

It appears that in this case also the parasites may be present in great numbers without pearls being found (Seurat (35), 1904, p. 295).

Here, again, examination of the scanty material available (see p. 346) has yielded no confirmation of the presence of Cestodes in the pearls of *M. margaritifera* var. *cumingii*. I am endeavouring to obtain further material from the Eastern Pacific, in order to extend my observations on this species.

I may say that from the first time I read Professor Herdman's Reports and papers on the subject I was sceptical as to the relationship of the Cestode to pearl-formation.

Indeed, before Prof. Herdman's departure for Ceylon, on examining Dr. Kelaart's material at the British Museum, which Mr. E. A. Smith kindly placed at my disposal, I had detected the existence of these Cestode larvæ (which Kelaart seems to have regarded as "eggs of Entozoa") in their connective-tissue cysts in the Ceylon pearl-oyster, and after having examined the larvæ, and also having decalcified pearls from the same oyster, dismissed the Cestode as probably not concerned in pearl-formation.

My chief grounds for doubting the Cestode theory were the following:—

(a) The absence of evidence that the Cestode ever occurred in an epidermal sac, and the fact that it was almost invariably surrounded by a fibrous capsule or cyst which does not occur around the pearl.

(b) The large proportion of the Cestodes that showed no sign of becoming pearl-nuclei, pointing to the conclusion that pearl-formation does not necessarily, or even normally, follow from infection. Thus, in a footnote to p. 12 of Part V. of his Report, Prof. Herdman says:

"In comparing these statistics [*i. e.* of numbers of parasites and of pearls in *Mytilus*] with those of the Ceylon pearl-oyster, one is struck by the wholly different ratio borne by pearls to parasites in the two cases. In the mussels, pearls are far more numerous than the living parasites. In our Ceylon oyster, parasites may be exceedingly abundant*; while pearls (cyst-pearls) are relatively very rare, probably not more than one to a hundred parasites."

* Mr. Southwell (42), p. 128, says: "As many as 120 have been counted in a single oyster"; and further down on the same page: "Occasionally several hundred oysters can be examined, each containing 20 or 30 cysts, and not a single pearl is to be found."

In this connection an observation made by Dr. Willey (49) is very significant. Dr. Willey says:—

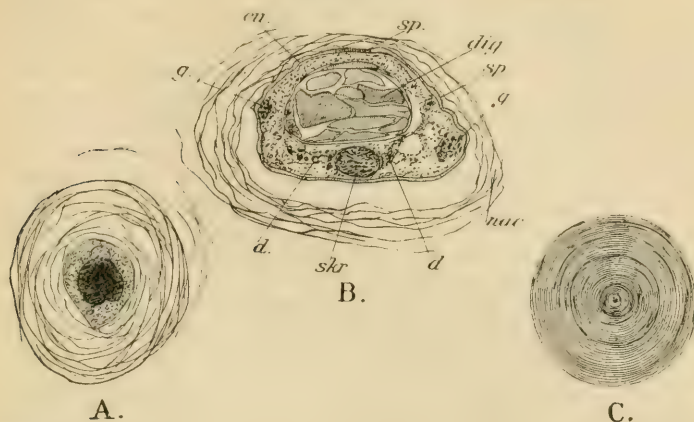
“A remarkable fact, indicating the subtle dependence of the pearl-producing molluscs upon their environment, is that whereas the most valuable pearls, called cyst-pearls by Prof. Herdman, are formed about a parasite as their centre or nucleus, yet the presence of these parasites in great numbers does not necessarily predetermine the formation of pearls. Pearl-oysters at Trincomalee may be heavily infected with the parasites without yielding pearls. It may be said that the parasitic infection and the pearl-disease are two separate phenomena, the latter proceeding from the former under certain conditions which are realised in the Gulf of Manaar. Whether these exact conditions can be reproduced elsewhere is one of the main problems before the Company. In the same way the cultivation of the oysters and the multiplication of pearls are two separate operations, the latter proceeding from the former in response to certain conditions affording the suitable stimulus. Conditions may favour the bivalves, but not their parasites; or they may favour both hosts and parasites, but not the production of pearls.”

(c) Professor Herdman's statement on p. 17 of Part V. of his Report that *Mytilus* pearls (which he examined in order to be able to correlate his work with mine) differed from Ceylon pearls in “the large size of the nucleus in the pearl (where a nucleus is present) and its characters, which are quite different from those of the encysted parasites in the Ceylon Pearl-Oyster.” Now the nucleus of a *Mytilus* pearl is generally about 0·5 mm. in diameter—the size of the Trematode when contracted into a sphere. As the Ceylon Cestode-parasite measures roughly from 0·5 to 1 mm. in diameter, the nucleus of a Ceylon pearl, if composed of its calcified remains, should if anything be larger, rather than smaller, than that of a *Mytilus* pearl. And the characters of the nucleus should not differ greatly—the dark opaque yellowish or brownish substance formed by the decomposition and subsequent calcification of the parenchymatous and muscular tissues of a Trematode should not differ materially in appearance from the analogous remains of a dead Cestode.

For purposes of comparison I figure below (text-fig. 33, A & B) a Trematode pearl from *Mytilus*, from Foulney, Lancashire (Preparation CIII). A shows the pearl decalcified and examined entire in oil of cloves, B shows the nucleus in section. In both cases the foreign nature of the nucleus is obvious, quite apart from the fact that in this preparation its Trematode character is quite clear (which would, of course, not be the case where decomposition had advanced considerably before calcification commenced). The characters of this nucleus are quite different from those of the pseudo-nuclei of Ceylon pearls figured in the

plates, the concentric stratification of the majority of which never occurs in a Trematode nucleus, and could hardly be expected in a Cestode.

Text-fig. 33.



A *Mytilus* pearl, from Foulney, near Piel, Lancashire, with a Trematode nucleus: A, examined entire in oil of cloves, after decalcification; B, the same in section. In A the oral sucker and digestive caeca of the worm are distinctly visible. In B the internal anatomy is still preserved. *cu.*, cuticle; *sp.*, spines on same; *dig.*, digestive caecum; *skr.*, ventral sucker; at *d* and *g* are dark masses, which may well represent the remains of the yolk-glands and gonads; *nuc.*, naere. C, a *Mytilus* pearl of non-Trematode origin, from Plymouth. Here the nucleus is, as in many Ceylon pearls, a minute group of granules. A $\times 20$; B $\times 70$; C $\times 20$.

As Mr. Cyril Crossland, Marine Biologist to the Sudan Government, is quoted by Professor Herdman (Report Ceylon Pearl Fisheries, Pt. V. Pearl-Production, p. 3) as supporting the Cestode theory, so far as *M. vulgaris* in the Red Sea is concerned, I wrote to him to ask him for further information. He replied, in a letter dated December 9th, 1911:—"I never published any statement that Cestode larvæ caused pearl-formation in the Red Sea. The evidence to my mind is in need of revision. In all cases the first result of excessive stimulation of the secretory epidermis of the mantle is the formation of a dark brown horny material [*i.e.* my amorphous substance.—H. L. J.]. How would this stain in sections, and is it cellular like the horny material of the prismatic layer? If so, would not a shrunken nucleus of such material resemble the dry remains of a Cestode? This is a criticism which I have had in mind several years, and have never put it to the test." From this it is clear that Mr. Crossland, though cut off from the possibility of applying modern laboratory technique, has arrived at much the same conclusion as that which I am elaborating in this paper.

To summarise the supposed relation between Cestodes and

Pearls, as described by Professor Herdman and Mr. Hornell, the position is briefly this:—

- (1) Ceylon Pearl-Oysters were found to contain large numbers of Cestode parasites which occurred simultaneously with pearls, but which did not necessarily result in the formation of pearls.
- (2) The nuclei of the majority of "cyst-pearls" were thought to be identified as consisting of the remains of these parasites, though Mr. Hornell's figures of such nuclei are capable of other interpretation.
- (3) No satisfactory evidence was adduced of the Cestode having acquired a surrounding epidermal sac, such as is normally formed around the pearl-producing Trematode in *Mytilus*, though Prof. Herdman admits that this sac is essential for pearl-production. The first stages in the supposed process are therefore purely hypothetical and unsupported by observation, besides pre-supposing an abnormal departure from the parasite's usual habit.

The evidence in favour of the theory is mainly that the more highly infected the oysters are with these particular Cestodes, the richer they are in pearls. Thus it was observed in 1904 (Report III. p. 32) that the oysters from the North-West Cheval, besides being the most extensively infected with Cestode-cysts were also the richest in cyst-pearls. And, again, Mr. Southwell records (40, p. 194), that

"the infection of the very old oysters [with tapeworm-cysts] found on the Kondatchi Paar in 1908 was remarkably low, and, as bearing practical proof that infection and pearl yield are intimately connected, it is interesting to note that the pearl yield also was remarkably low, the valuation only working out at about Rs. 18 per 1,000 oysters."

These facts might be explained, however, on the assumption that the conditions favourable to pearl-production are also favourable to Cestode infection.

Characters, Identity, and Life-Histories of the Cestode Parasites of Margaritifera vulgaris.

Apparently the first announcement of the supposed relation between the Cestode and pearl-production was made by Prof. Herdman at his Royal Institution lecture on March 27th, 1903 (14). In this he says that he and Mr. Hornell have proved so far "that in Ceylon the most important cause is a larval Cestode of the *Tetrarhynchus* form." Again, in the Report of the British Association, Southport, 1903, p. 695, Prof. Herdman says: "The parasite in the case of the majority of the cyst-pearls of Ceylon is the larva of a Cestode which appears to be new, and will be described under the name of '*Tetrarhynchus unionifactor*'"; and the pearl-inducing parasite is referred to throughout Prof. Herdman's Report under this name.

But the worm specifically described by Shipley and Hornell as *Tetrarhynchus unionifactor* on p. 88 of Part II. of Prof. Herdman's Report (Parasites of the Pearl-Oyster) and figured in plate ii. figs. 19 & 20, is a well-advanced *Tetrarhynchus* 6·5 to 7 mm. long, which occurs in and around the intestine of the Pearl-Oyster; and, to say the least of it, it is doubtful whether this worm is a later stage of the globular cysts, which Prof. Herdman identified as the nuclei of pearls, and not an entirely distinct organism. In order to avoid confusion of terms I am therefore giving separate names to the larger and smaller globular Cestode larvæ which Herdman recognises, as it is calculated to lead to much confusion of issues if these are referred to by the name of *Tetrarhynchus unionifactor* before their identity with it can be demonstrated more satisfactorily. The arguments for regarding the supposed pearl-producing parasites as distinct from *Tetrarhynchus unionifactor* are set forth below. In the absence of satisfactory evidence of their relation to the genus *Tetrarhynchus*, I propose, following Seurat (36), to whose larval Cestode, mentioned above, they bear a close resemblance, to refer them to the genus *Tylocephalum** and to describe the larger and smaller forms respectively as *Tylocephalum ludificans*, sp. n., and *Tylocephalum minus*, sp. n.

Two well-marked sizes occur in these globular larvæ and they are regarded by Herdman as distinct organisms (Report V. p. 21). On the other hand, Southwell considers that the asexual reproduction, which he has occasionally observed, accounts for the varying sizes of the larvæ in the Ceylon Pearl-Oyster, and says: "I am now convinced that these different sizes merely represent the same species in different grades of development." I am inclined to share Prof. Herdman's view that these two sizes are distinct organisms. It may even prove that there are more than two species represented. Indeed, I should not be surprised if further research on fresh material were to show that both *Tylocephalum ludificans* and *T. minus* are composite species.

Professor Herdman regards *T. ludificans* as the earlier stage of *Tetrarhynchus unionifactor*, and calls attention to its resemblance to Van Beneden's ideal figures of the young of *Tetrarhynchus*, while he treats *T. minus* as another species of *Tetrarhynchus* in its earlier stages. Nevertheless, he seems to have had suspicions that some, at least, of these larvæ might be *Tylocephala*, though he appears in the end to have decided that they—and presumably with them Seurat's larva—are a hitherto unknown stage in the life-history of the genus *Tetrarhynchus*.

In the Preface to Part II. of his Report he says (p. vi):—

"It is possible that some of our Ceylon Pearl-Oyster parasites may also belong to the genus *Acrobothrium*" [*i. e.* the genus to which Seurat's larva was then referred], "although the more advanced ones are certainly Tetrarhynchids";

* Linton (27 a), pp. 805-9, pl. ix. figs. 5-9. Type *T. pingue*, from spiral valve of *Rhinoptera quadriloba*.

while in Part V. of the Report, p. 14, he and Hornell say :—

“Some of our Ceylon Pearl-Oyster parasites very closely resemble the figures given by Giard” [*i. e.* of Seurat’s larva] “and possibly may also belong to the genus *Cyathocephalus* [*Tylocephalum*], although most of them are certainly Tetrarhynchids”;

and on pp. 16-17 :

“It is possible, however, that more than one species of Cestode is represented—one is certainly a species of *Tetrarhynchus* (*Rhynchobothrius*), and another is probably the same genus, or may possibly belong to *Cyathocephalus* . . .”

Later on, however (p. 20), Herdman and Hornell reject the idea that the globular larvæ may be *Tylocephala* or allied genera, and, in discussing the opinions of Giard and Seurat on the systematic position of Seurat’s larva, they say that they regard the terminal invagination, not as a sucker with a papilla on its floor, but as

“the opening in a hood or depression formed by the sinking of the scolex into the front of its vesicle. The changes of shape which we observed in this larva in the living state, the protrusion and retraction of the papilla-like part which we regard as the anterior end of the scolex, agree with this interpretation. Consequently, we are of opinion that this larval Cestode is not one of the Monobothria—that it belongs to neither the Pseudophyllidea nor the Tetraphyllidea, but is a young Tetrarhynchid belonging to the Trypanorhyncha, and we give here (fig. 4) a series of diagrams in order to show the positions that we suppose our stages to occupy in the development of such a form.”

Shipley and Hornell (Herdman’s Report II. p. 80) call attention to the resemblance of older examples of the larger larva (*Tylocephalum ludificans*) to Seurat’s form, and think there is little doubt that they are at least generically the same (p. 82). Again, Southwell says (39, p. 169) :

“It would certainly appear more probable as well as simpler, for this larva to develop into a *Tylocephalum* (as is believed by Seurat) than into a *Tetrarhynchus*.”

Again, Southwell, speaking of the great scarcity of the adult of *Tetrarhynchus unionifactor* in Elasmobranchs taken by trawling, says (42 p. 130) :

“It would almost appear that this fact in itself is sufficient proof that the adult of the pearl-inducing worm is not *Tetrarhynchus unionifactor*.”

But at the foot of the same page he reverts to the position that it is a *Tetrarhynchus*.

It is strange how the *Tetrarhynchus unionifactor* theory, once enunciated, has prevailed:—indeed nobody seems to have seriously followed up the obvious clue given by Seurat's discovery of the supposed adult of his worm.

Prof. Herdman says in his Report, Part V. pp. 20–21 :

“Shipley and Hornell in Part II. (p. 77) described and figured various stages of the Cestode larvæ both from the centre of decalcified pearls and also free in the tissues of the pearl-oyster, but left it an open question whether the sub-globular younger larvæ [i. e. *Tylocephalum ludificans*, n. sp.] belong to the same life-history as the elongated older forms, which are young Tetrarhynchids. If our arrangement of the stages observed in the tissues of the pearl-oyster is correct, and if all these larvæ belong to the same species, then the interpretation we have given above brings us to the conclusion that the larger of our two globular larvæ belongs to the worm which Shipley and Hornell described as *Tetrarhynchus unionifactor* in 1904.”

And, referring to some figures of *Tylocephalum ludificans* on pl. iii. (Report, Part V. Pearl-Production) figs. 1–8, he says (p. 21):

“there can scarcely be any doubt (1) that they all belong to the same life-history, and (2) that they are young Tetrarhynchids leading on to the stages shown in figs. 10 and 11.”

Prof. Herdman gives, in support of his theory, a series of figures showing the hypothetical transition from *Tylocephalum ludificans* to *Tetrarhynchus unionifactor* (Report, Part V. p. 21).

Later, a younger *Tetrarhynchus*, 1 mm. in length, was found in the stomach and alimentary canal of the oyster, which Shipley and Hornell (Report V. pp. 87–88) regarded as probably an earlier stage of *Tetrarhynchus unionifactor*, though possibly a distinct form. A single example of a still younger form, which is figured in the Report on Pearl-Production (V., pl. iii. fig. 10), and is described in the text (p. 22) as occurring “encysted in the liver” and in the explanation of the plates as “from cyst between stomach and liver,” appears to go still further towards linking the two forms. This larva is referred to in the text as .53 mm. long. *Tylocephalum ludificans* grows to a much greater size than this without changing its characters; thus the one figured by Shipley and Hornell in the “Parasites of the Pearl-Oyster” (Report, Part II. pl. i. fig. 12), and described as $\times 40$, appears from the size of the figure to be over 1.5 mm. long, and still shows no sign of becoming a *Tetrarhynchus*. And *T. ludificans* quite frequently measures 1 mm. in diameter. This discrepancy in dimensions makes it hard to believe that they are the same organism, and the gap between the *Tylocephalum* form, with its round *Balanoglossus*-like scolex or “myzorhynchus,” and the

Tetrarhynchus form, with its complex proboscides, cannot be said to have been satisfactorily bridged.

Herdman found the *Tetrarhynchus* form much scarcer than the *Tylocephalum* form, and it appears from his Report, Part V. p. 22, that the ratio of the latter to the former is about 200 : 6. Shipley and Hornell (Report, Part II. p. 79) give the ratio of globular larvæ to undoubted *Tetrarhynchi* as 100 : 1.

Prof. Herdman's suggested explanation of this, namely, that the globular parasite only occasionally advances to the *Tetrarhynchus* stage, requires, it seems to me, a greater effort of the imagination than the hypothesis that the two worms are distinct forms.

It is hard to conceive of conditions that would lead a small minority of *Tylocephalum ludificans* or *T. minus* to leave their tough fibrous cysts in the peripheral tissues, and migrate to the intestine, there to take on the *Tetrarhynchus* form. It seems to me much easier to regard these as two (or three) distinct species, and their simultaneous presence in one host as a case of parallel infection.

In his latest paper (42, p. 129), Southwell, speaking of these undoubted *Tetrarhynchids*, says :—

“These are by no means rare, and are in almost every case confined to a particular part of the wall of the gut, about one inch from the anus and on the terminal part of the gut. They often occur in clusters of three or four. They are small (about 1 mm.), but appear to be adult in every way, save that strobilization has not commenced. This encysted young *Tetrarhynchid* is quite dissimilar to the globular cysts found in the same oyster. In the latter case, the larvæ are so young that the Cestodian characters are but ill defined. In the former case, a normal and full-grown *Tetrarhynchid* head is present. No stage or stages have been found intermediate between them, and the evidence that they are both stages in the life-history of the same parasite rests on circumstantial evidence and on evidence obtained by feeding experiments.”

And with reference to these feeding experiments, which are referred to below (p. 287), and in which *Tetrarhynchi* were found in Sharks that had been fed on pearl-oysters, Mr. Southwell says (p. 130):—

“The mere fact that the adults were obtained by feeding is in itself almost sufficient to prove that they are the adult of the pearl-inducing worm, for it is difficult to believe that their occurrence in the *Ginglymostoma* was a mere coincidence each year.”

I think there is very good reason to believe that Southwell did, in his feeding experiments, actually transmit *Tetrarhynchus unionifactor* from the Oyster to the Elasmobranch, but it is

difficult to escape the conclusion that the worms found in *Ginglymostoma* were derived from the *Tetrarhynchus* larvæ in or around the alimentary canal of the Oysters, and not from the globular *Tylocephala* in the other tissues, to which Southwell refers when he speaks of the "pearl-inducing worm." To dispute this view, it would be necessary to demonstrate that the *Tetrarhynchus*-stage was not present in the Oysters used.

Shipley remained throughout sceptical about the identity of the supposed pearl-forming larvæ with *Tetrarhynchus unionifactor*. In Part II. of Herdman's Report, p. 86, he says it is most improbable that the young larvæ grow into the *Tetrarhynchus* larva. In their report on the Cestode and Nematode Parasites from the Marine Fishes of Ceylon, Shipley and Hornell say (Pt. V. p. 66):—

"It seems increasingly probable that the pearl-forming Cestode is a *T. unionifactor*, but this has not yet been proved."

Shipley and Hornell, in Herdman's Report, Part V. p. 98, offer the following hypothetical life-history:—

"Of the given number of larvæ which enter at a very early stage into the body of the Oyster a certain number arrive in the mantle and other tissues, acquire an ectodermal sac and there encyst, and find a costly grave in the developing pearl." [The ectodermal sac around these parasites is so far purely hypothetical and has never been demonstrated.—H. L. J.] "The remainder, however, reach the alimentary canal and grow and flourish there. When they attain the dimensions of the stages described in Part II. they leave the alimentary canal and encyst, usually upon the outer surface of the intestine. Now they are too big for enclosure in a pearl, and they can wait without anxiety for the advent of their second host (*Rhinoptera javanica*), within whose intestine they rapidly become sexually mature."

It would seem to the present writer much simpler to set aside, for a while, the hypothesis that *Tylocephalum ludificans* and *T. minus* are younger stages of a *Tetrarhynchus*, and to seek for their adult stages among the members of the genus *Tylocephalum*, or allied types described as new genera, occurring in oyster-eating Elasmobranchs. Shipley and Hornell have already described a number of these, which I give below:—

*† *Tylocephalum* (*Tetragonocephalum*) *trygonis* (Report, Part III. p. 51 and Part V. pp. 48 & 83). *Habitat*: intestine of *Trygon walga* and *Aëtobatis narinari*. Diameter of head 0.03 mm.

* *Tylocephalum* (*Tetragonocephalum*) *aëtobatidis* (Report, Part III. p. 52 and Part V. p. 48). Intestine of *Aëtobatis narinari*. Diameter of head 1.5 mm.

†*Tylocephalum dierama* (Report V. p. 59). Intestine of *Myliobatis maculata*. Diameter of head .6 mm.

Tylocephalum kuhli (Report V. p. 72). Intestine of *Trygon kuhli*. Head apparently about .5 mm. in diameter.

†*Tylocephalum uarnak* (Report V. p. 76). Intestine of *Trygon uarnak* and *Trygon walga*. Head apparently about 1 mm. in diameter.

*†*Cephalobothrium aëtobatidis* (Report V. p. 44). Spiral valve of *Aëtobatis narinari*. Diameter of head .5 mm.

*†*Kystocephalus translucens* (Report V. p. 46). Intestine of *Aëtobatis narinari*. Diameter of head .4 mm.

**Eniochobothrium gracile* (Report V. p. 64). Intestine of *Rhinoptera javanica*. Head appears to measure about .4 mm. in diameter.

*†*Tiarabothrium javanicum* (Report V. p. 67). Intestine of *Rhinoptera javanica*. Head 1 mm. broad.

To these may be added two forms described by Mr. Southwell (41 a), viz.:—

Cephalobothrium abruptum, from the spiral valve of *Pteroplatea micrura*. Head 1.2 mm. broad.

Cephalobothrium variabile, from the intestine of *Pristes cuspidatus*. Head 1 mm. broad.

The forms marked * occur in hosts which are known to feed on pearl-oysters. Those marked † I have been able to examine through the courtesy of Dr. Shipley. It is impossible not to be struck with the resemblance between the heads of some of the above species and the parasites which Herdman associates with pearl-formation. Compare, for example, the head of *Cephalobothrium aëtobatidis*, figured in Part V. (Cestoda) plate i. figs. 1-4, with some of the figures of *Tylocephalum ludificans* in the chapter on Pearl-Production (Part V. Pearl-Production, plate iii.) or the heads of *Tylocephala* (*Tetragonocephala*) as figured on the plate of Part III. (Parasites), and in the article on Cestodes in Part V. (pl. v. figs. 76-7), with some of the figures in the article on the parasites of the Pearl-Oyster in Part II. Or, again, compare the section of *Tylocephalum ludificans* from the pearl-oyster shown on Pl. XLVI. fig. 58, with the head of *T. uarnak*, Pl. XLVII. fig. 65, drawn from one of Dr. Shipley's slides, as a representative of the genus *Tylocephalum*, taking into account the difference that in the former the myzorhynchus is withdrawn within the collar, whereas in the latter it is fully protruded. Or compare Pl. XLVI. fig. 59, a section of *T. ludificans* from the pearl-oyster, with the head of *Cephalobothrium aëtobatidis*, from one of Dr. Shipley's slides shown on Pl. XLVII. fig. 66. Similarly, compare figs. 58 & 59 with the worm shown in figs. 61 & 62 on Pl. XLVII., also from *Aëtobatis narinari* (the final host of Seurat's larva) ‡. I think the worm shown in figs. 60-64 is quite probably

‡ It is strange that the oyster-eating habits of this Ray do not seem to have been recorded in these Ceylon researches.

the adult of *Tylocephalum ludificans*—in fact, the only difference appears to be the presence of the four lateral suckers, which are absent in the larva, but which may well not develop till its transference to the final host.

Comparison of these figures makes one feel doubtful whether the generic distinction between *Tylocephalum* and *Cephalothrium* is a valid one, or whether the conditions shown in figs. 58 & 65, and in figs. 59 & 66, are not merely the expression of a uniform type of myzorhynchus in different stages of contraction, as suggested diagrammatically in the following text-figure.

Text fig. 34.

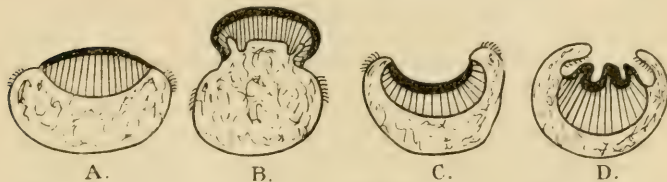


Diagram illustrating the relationship between the condition of the myzorhynchus in *Tylocephalum* and *Cephalothrium*. A, a generalised scheme of a scolex such as the *Tylocephala* of the pearl-oyster. B, by protrusion of the myzorhynchus, the outer surface of the same being tense, the inner surface thrown into folds, the *Tylocephalum*-form may be produced (compare Pl. XLVII. fig. 65). C, the partial retraction of the myzorhynchus to form a sucker-like disk gives the *Cephalothrium* condition (compare Pl. XLVI. fig. 59 and Pl. XLVII. fig. 66). D, the myzorhynchus retracted within its collar, with its outer surface thrown into folds, as is characteristic of many of the larvae of *Tylocephalum ludificans* found in the pearl-oyster, and of the adult worm figured on Pl. XLVII. figs. 61-62.

It does not necessarily follow that any of the above mentioned worms actually represents the final stage of *Tylocephalum ludificans* or *T. minus*, though I think there are considerable grounds for regarding the worm shown at figs. 60-64 as the former; but it certainly appears more probable that these final stages will be found among this class of parasites rather than among the *Tetrarhynchi*, and it is strange that the position that the *Tetrarhynchus unionifactor* hypothesis may be wrong has never been seriously faced and a fresh start made on the above lines.

It is not known how *Tylocephalum ludificans* and *Tylocephalum minus* enter the Pearl-Oyster; but Hornell found, in tow-netting on the Muttuvarattu Paar on the 19th November, 1902, a free-swimming larva, .37 mm. long when extended, which is figured in Prof. Herdman's Report (Part II. Parasites of the Pearl-Oyster, plate i. fig. 1a-h). This larva certainly suggests an earlier stage of *Tylocephalum ludificans*, and one of the chief difficulties in the way of accepting it disappears if this worm is dissociated from the genus *Tetrarhynchus*, the normal habit of which is to enter the digestive canal with the food while still in the egg-

stage. (The fact that the undoubted *Tetrarhynchi* in the pearl-oyster occur in and around the digestive canal suggests that they follow the normal course and are swallowed in the egg-stage, and first hatch out in the intestine of the oyster.) Mr. Southwell states (Ceylon Marine Biological Reports, Part IV. No. 6, p. 169, 1910) that this free-swimming larva has not been seen since it was first discovered (see also 42, p. 127).

I may here mention that one of Prof. Herdman's slides which I examined shows an interesting phase in the biology of these supposed pearl-inducing Cestodes which may have escaped him. It shows a small Cestode, 0.12 mm. long, with myzorhynchus and collar fully developed, clearly in the act of passing through the tissues. This may possibly represent the young of either form, when first entering the oyster, or it may be a case of voluntary or accidental migration by *Tylocephalum minus* (Pl. XXXIII. fig. 1). Dr. Willey (48, p. 50) records a similarly free larva seen moving about in the liver of a species of *Venus*.

To return to the life-history of the true *Tetrarhynchus unionifactor*, Shipley and Hornell have shown without doubt that the adult sexually mature worm occurs in the Ray, *Rhinoptera javanica* (Herdman's Report V. Cestodes, pp. 65-66). The identification of the final host as *Rhinoptera javanica* is announced by Mr. Hornell in a postscript to his Report on the November Inspection of the Pearl Banks, 1904 (20, p. 8). Mr. Southwell (42, p. 130) gives *Tæniura melanospilos* as another host.

Professor Herdman in his Royal Institution Lecture, and in Pt. I. p. 12 of his Report, claimed the File-fish, *Balistes*, as an intermediate host; but Shipley and Hornell, in Herdman's Report, Part II. p. 83, say that "a more minute examination, however, renders the connection between the parasites of the pearl-oyster and those of the file-fish a doubtful one"; and the immature *Tetrarhynchi* found in this fish are described as distinct species under the names of *Tetrarhynchus balistidis* and *T. pinnae*. Prof. Herdman sums up the position in the article on Pearl-Production (Report V. p. 24) by saying:—

"No fresh light has been thrown upon the possible occurrence of an immature stage in *Balistes* (which is eaten by the large rays), and although that intermediate host may not be necessary to the life-history, since the rays also feed upon pearl-oysters, still there is nothing in the observed facts to forbid the existence of such a stage, and it is not unusual in *Tetrarhynchids* to have two fish-hosts, an intermediate Teleostean which is devoured by a final Elasmobranch."

Mr. Southwell's subsequent investigations confirm Prof. Herdman's view that *Balistes* occurs as a collateral intermediate host or "carrier"; he says (42, p. 132):—"It is certain that my encysted *Tetrarhynchus unionifactor* from *Balistes* is not the same species as those described" (*i. e.* by Shipley and Hornell

from *Balistes*); and he claims that they are "exactly similar to the encysted Tetrarhynchid found in the oyster"—i. e. the true *Tetrarhynchus unionifactor*, except that they are slightly larger. Mr. Southwell is satisfied that they are derived from the oysters eaten by *Balistes*, and thinks that they are derived from both the genuine Tetrarhynchids in the Oyster's intestine and from the globular cysts in its tissues. He considers that if *Balistes* is eaten by an Elasmobranch, the young worms become adult; but *Balistes* is not a *necessary* host, it is merely a "carrier."

Johnstone (26 b) confirms the view that the Teleostean host is a collateral one, and not a normal stage in the life-history, by his recent researches on the European *Tetrarhynchus erinaceus*. The adult stage of this worm occurs in various species of Skates and Rays, and the first host is probably some Invertebrate. Johnstone regards the frequent occurrence of a larval form of this worm in Teleosts as a "cul-de-sac" stage, due to the first host being eaten by the wrong fish; and as normally leading no farther, but ending in degeneration.

Mr. Southwell has further shown (38) that the adult *Tetrarhynchus unionifactor* occurs also in the Shark, *Ginglymostoma concolor*. This fish was doctored with Male-fern and castor-oil, and subsequently fed on pearl-oysters; but Mr. Southwell does not claim that the *Tetrarhynchi* were actually derived from these pearl-oysters, though he is inclined to think they were. The same experiment was subsequently repeated [Southwell (41)] and *Tetrarhynchus unionifactor* was again found in *Ginglymostoma concolor*; and while Mr. Southwell admits that his results are not altogether conclusive, it seems highly probable that the infection was in fact induced by his feeding experiment. There is nothing, however, to show that the adult tapeworms in *Ginglymostoma* were derived from the globular cysts in the oysters; it seems more probable that they were derived from the *Tetrarhynchi* in the oysters' intestines.

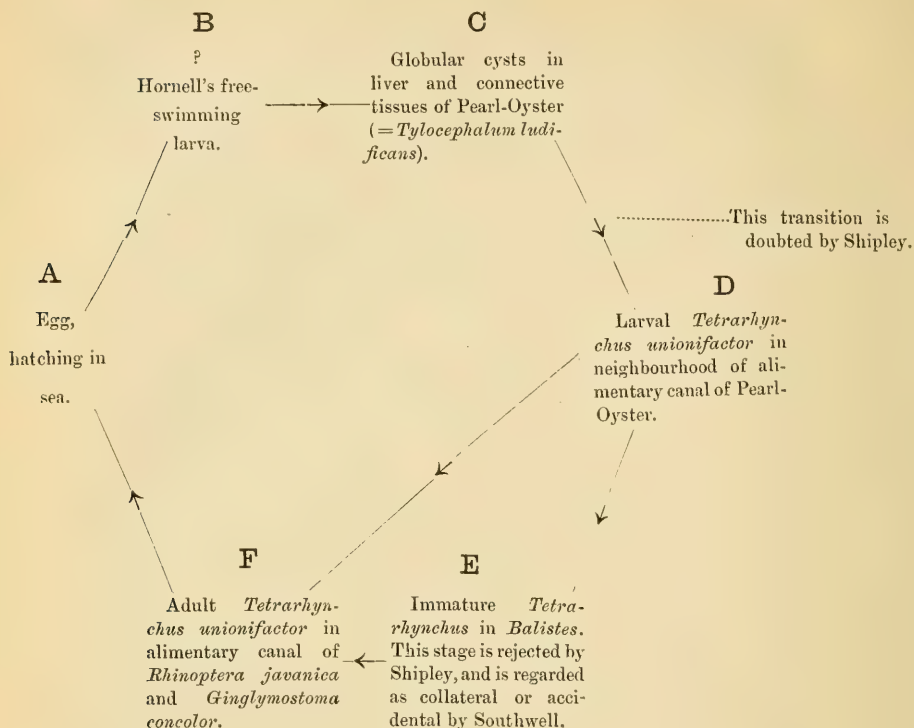
These elaborate experiments are, of course, chiefly of academic interest, in the absence of proof (1) that the *Tetrarhynchi* are a later stage of the globular cysts, and (2) that the latter are concerned in pearl-formation.

To sum up, then, the gap between (a) the resting scolex enclosed in its tough fibrous cyst in the connective tissues of the Pearl-Oyster and strongly suggesting by analogy with other forms—notably Seurat's larva—a young *Tylocephalum*, awaiting and ready for its final host to devour the tissues which contain it, and (b) the equally expectant, but much larger, *Tetrarhynchus unionifactor* in the wall of the oyster's intestine, has not yet been bridged.

I set out below diagrammatically the conclusions of Herdman, Hornell, Shipley, and Southwell, as to the probable life-history of these parasites, and also, for purposes of comparison, my own attempt at an interpretation of the facts.

DIAGRAM illustrating Prof. Herdman's conclusions as to the
life-history of the parasites.

Species I. *Tetrarhynchus unionifactor*.



Species II. "*Tetrarhynchus* sp."

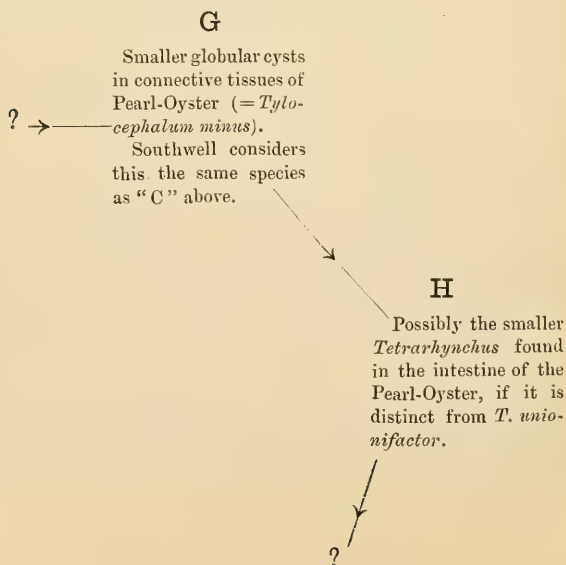
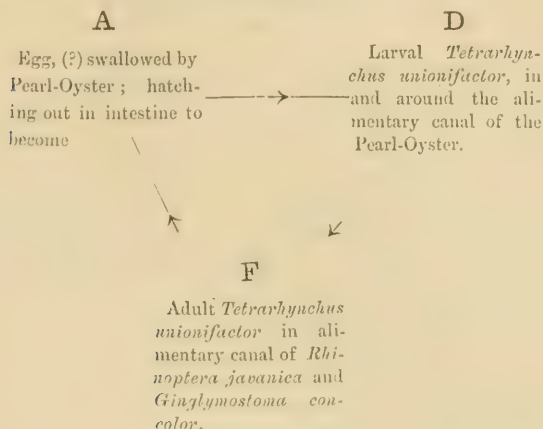


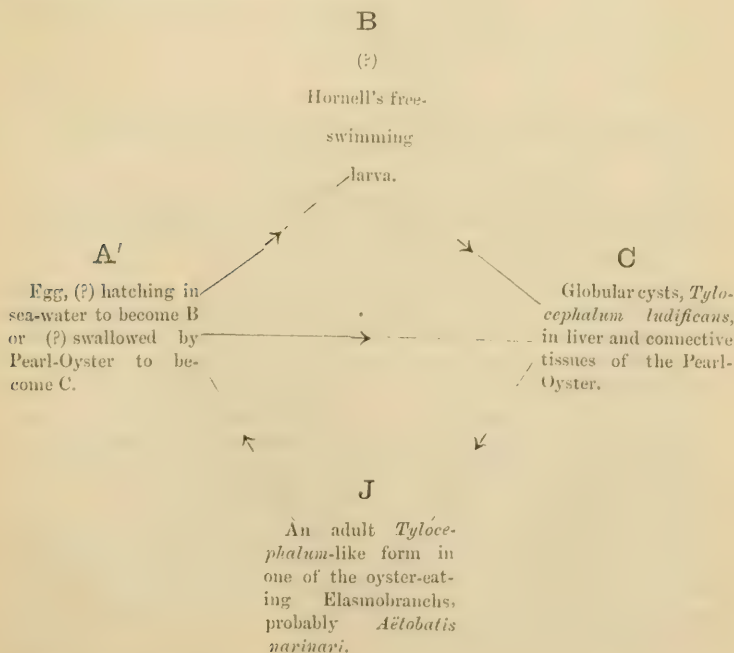
DIAGRAM illustrating my hypothesis of the relations of the several forms and stages of Cestode larvæ described in Herdman's Report.

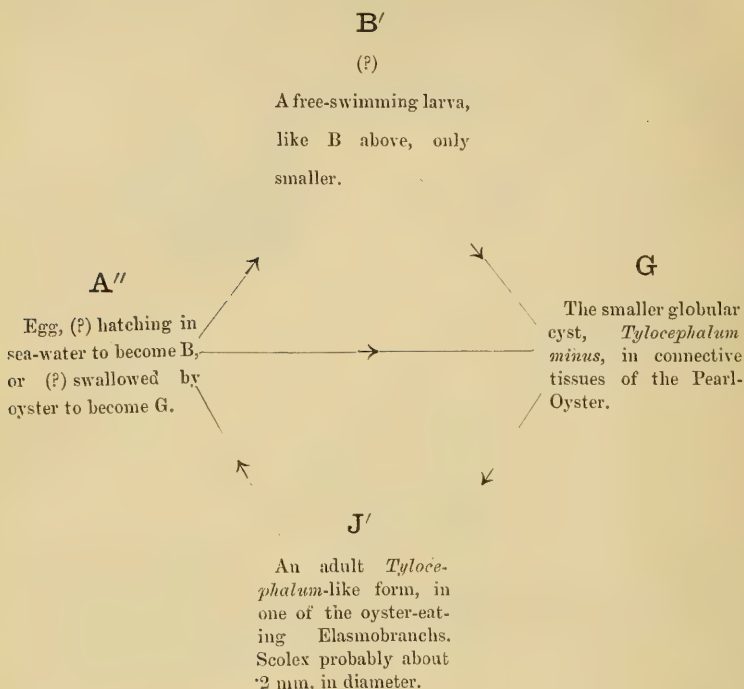
(The letters correspond to those in the above diagrams. Those marked A', A'', B', and J' are regarded as parallel stages to A, B, and J.)

Species I. *Tetrarhynchus unionifactor*.



Species II. *Tylocephalum ludificans*.



Species III. *Tylocephalum minus*.(5) DESCRIPTION OF THE TWO GLOBULAR CESTODE LARVÆ FROM
THE CEYLON PEARL-OYSTER.

I append the following descriptions. They are certainly incomplete, being based on examination of preserved material and on the descriptions of previous writers:—

***Tylocephalum ludificans*, sp. n.** (The larger globular larva; the supposed pearl-producing worm.) (Pl. XLVI. figs. 58 (type) & 59.)

The type, fig. 58, is in Slide 94 in Prof. Herdman's Collection.

Tetrarhynchus unionifactor (young) Herdman. (For other figures see Herdman's Report, Part II. Parasites of the Pearl-Oyster, pl. i. figs. 12 & 13; Part V. Pearl-Production, pl. ii. figs. 11, 12, & 17 b, pl. iii. figs. 1-5, 6, 7, 8, & 9; also Part V. p. 21.)

Globular Cestode larvæ, with rostrum or *myzorhynchus* (Linton) retractile within a denticulated collar. Form more elongated when liberated from capsule; length 0·5 to 1·5 mm. Average diameter of seven specimens sectioned on Prof. Herdman's slides and examined by the writer, 0·78 mm.

Myzorhynchus uniformly muscular, without obvious division into muscular tracts; retractile within an annular collar; in section it may appear either conical, lenticular, or flattened, concave and sucker-like; protrudes as a conical papilla when in locomotion. This anterior muscular region, including the collar, is about one-third of the total length of the larva when extended. The whole myzorhynchus can be protruded, the collar then forming an annulus around it.

Collar or cephalic sheath muscular with denticulated cuticle, the denticles tricuspid. (Herdman's Report, Part II. (Shipley & Hornell, Parasites of the Pearl-Oyster) pl. i. figs. 10, 11, & 14, pl. ii. fig. 18; also Pt. V. (Pearl-Production) pl. iii. fig. 9.)

The denticles measure from 3μ to 5μ in diameter.

Hinder part of the larva centrally parenchymatous, the parenchyma containing the calcareous corpuscles characteristic of Cestode larvæ, peripherally more muscular.

The hinder part of the body is covered by a thick, radially marked epicuticle, permeated by numerous closely-set tubuli, and suggesting on superficial examination a coat of cilia. This epicuticle varies in thickness but is generally about 0.03 mm. thick, and the true cuticle lies under it.

This form is distinguished from the next described worm by its larger size (Herdman gives the size as about six times that of the smaller form), the undivided musculature of the myzorhynchus, and the wider and more open character of the collar-sheath of the myzorhynchus in the resting-stage.

Habit. Resting in spherical fibrous cysts, derived from the connective tissue of the host, in the Ceylon Pearl-Oyster, *Margaritifera vulgaris*. Most frequent in the visceral mass, notably the liver.

Habitat. Gulf of Manaar (Herdman & Hornell). Trincomalee (Willey).

The following is a description of a worm which I regard as in all probability the adult of this larva. The single specimen was obtained from the spiral intestine of *Aëtobatis narinari*, by Mr. Hornell, on 4th January 1905, and had apparently been overlooked by Mr. Shipley among some duplicate specimens of *Kystocephalus translucens*, along with which I found it when examining Dr. Shipley's material. After it had been cleared and examined as a transparent object, Dr. Shipley very kindly allowed me to have sections cut from it to compare with those of the larva in the pearl-oyster.

(?) Adult of *Tylocephalum ludificans*, sp. n. (Pls. XLVI. & XLVII. figs. 60-64.) Length 12 mm. Head 0.6 mm. long by 0.5 mm. broad; pyriform, slightly broader in front than behind; transition from head to neck not very sharply defined. The myzorhynchus in this specimen is retracted within its sheath, as is usually the case with the larva in the pearl-oyster; it is about .3 mm. in diameter. Around the head are four marginal suckers about .125 mm. in diameter. Proglottides about 140 in number, increasing but little in breadth from before backwards; they

begin to increase notably in length from about the 85th backwards. The largest hindmost segments are about .5 mm. long, and slightly longer than broad (fig. 64). The armature of the collar *a* (in figs. 61-63) is similar to that of the larva. In section (fig. 62) the myzorhynchus is seen to be retracted in such a way that its anterior surface is thrown into folds, thus resembling the condition of the larva shown in fig. 59. The only point in which the head of this worm appears to differ from the larva in the pearl-oyster is in the presence of the four marginal suckers, which may well be a feature first acquired in the final host.

Tylocephalum minus, sp. n. (Plate XXXIII. fig. 2.) (The smaller globular larva, which Prof. Herdman thinks may also be concerned in pearl-formation.)

(*Tetrarhynchus* sp., Herdman.)

For other figures see Herdman's Report (Pearl Production), Part V. pl. ii. figs. 1-3, 17A, 18-22; also text-figure 3, p. 19.

Diameter of resting parasite in cyst from 0.07 to 0.2 mm. Average diameter of 40 examples shown on Prof. Herdman's slides and measured by the present writer, 0.14 mm. Body subglobular, consisting, as in *T. ludificans*, of an anterior muscular and a posterior parenchymatous part, the anterior muscular portion (myzorhynchus) consisting of a conical papilla in a cup- or flask-shaped depression formed by the surrounding muscular collar or sheath. As a rule, in preserved specimens, the opening of this depression seems relatively narrower, and the papilla more conical and less flattened than in the previous species. The musculature of the myzorhynchus shows, in some examples, a tendency to break up into four longitudinal tracts. In young examples the myzorhynchus may be barely differentiated. Cuticular spines are present on the collar, but they are smaller and relatively finer than in *T. ludificans*. The epicuticle is about .01 mm. thick.

This form is distinguished from *T. ludificans* by its smaller size and finer armature of the collar, and by the tendency of the myzorhynchus musculature to break up into four strands. It is regarded by Southwell as the same species as *T. ludificans*.

Habit. Resting in spherical fibrous cysts in the connective tissues of *Margaritifera vulgaris*, occurring in the visceral mass, mantle, gills, etc.

Habitat. Gulf of Manaar.

Prof. Herdman, while he regards the form here named *T. ludificans* as the pearl-producer *par excellence*, considers that the present species too "may occasionally form the nuclei of pearls" (Report V. p. 22).

Particulars of the structure of both these forms are given on pp. 79-82 of Part II. of Prof. Herdman's Report.

(6) OBSERVATIONS ON THE STRUCTURE OF THE FIBROUS CYSTS SURROUNDING THE CESTODE LARVÆ IN *MARIGARTIFERA VULGARIS*.

I may here add a few notes on the structure of the investing cysts of *Tylocephalum ludificans* and *T. minus*, based upon my examination of Professor Herdman's slides and Dr. Kelaart's material.

In the earliest stages the cyst may be scarcely differentiated from the surrounding tissue, and about 0.01 or 0.02 mm. thick. This condition I find specially associated with a little-developed phase of the smaller larva *T. minus*, measuring 0.08 mm. in diameter, and resembling B in figure 4 on p. 21 of Part V. of Herdman's Report. In such thin cysts the nuclei of the fibres are distinct, though hardly more so than those of the general connective tissue of the oyster. One or two examples at this and later stages were found in the muscular tissue without any surrounding cysts at all, beyond a little of the interstitial tissue of the muscle-bundles (Pl. XXXIII. fig. 2). As the fibrous capsule becomes thicker the nuclei appear at first to become more abundant, and this may well be associated with the growth and multiplication of the fibres. As a rule, the thicker cysts (0.2 mm. thick and over) seem to be less densely nucleated, and may even show very few nuclei, especially when they become highly areolar and œdematous. The outer part of the cyst is usually ordinary areolar connective tissue, with branched and anastomosing fibres passing over, often quite imperceptibly, into the general connective tissue of the body, such as occurs between the tubules of the liver. The cyst is, however, typically lined with several layers of more regular parallel fibres, with abundant nuclei. In some cases the fibres seem to coalesce to form a dense almost gristly substance, without obvious nuclei.

The nuclei of the fibres are long and narrow, and are situated on their outside edges.

In some cases the cyst appears to be entirely without nuclei, and in such cases the fibres are often very thick, measuring as much as 10 or 15 μ in diameter.

There is never, so far as I can see, any trace of a lining epithelium, though the cyst may be lined with a layer of granules, possibly derived from the Cestode or from the leucocytes of the blood.

In certain cases large dark-staining bodies were seen in the areola of the fibrous connective tissue of the cyst, which suggested parasitic Sporozoa, but the preparations did not allow of detailed examination.

A typical section of the cyst of the smaller parasite, *Tylocephalum minus*, is shown on Pl. XXXIII. fig. 3.

This condition of things is very different to that which is found in the case of the pearl-inducing Trematode of *Mytilus* described in my paper (25). Here the parasite is surrounded by an

epidermal sac (*l. c.* pl. xv. fig. 5) of the same nature as the outer shell-secreting epidermis. In such a case it is easy to understand how the parasite, when it dies, becomes encased in a pearl, laid down, layer upon layer, by this epithelium*.

(7) MATERIALS AVAILABLE FOR THE PRESENT INVESTIGATIONS.

I have throughout these investigations been seriously handicapped by the extreme difficulty of obtaining material. Many of the points which remain obscure could probably be cleared up if I could obtain properly preserved specimens of pearl-bearing oysters from the Gulf of Manaar. Unfortunately, I have been quite unable to obtain these.

I endeavoured to do so through the Ceylon Company of Pearl Fishers, Ltd., and Mr. Southwell, but without success, Mr. Southwell replying that there were no oysters on the banks and that his own preserved material was finished. The Company, however, kindly forwarded to me a suggestion made by Mr. Southwell to the following effect:—

“As it is probable Dr. Jameson requires Ceylon pearls (with the particular parasite giving rise to same), I would suggest that in order to ensure that the pearls are from Ceylon that they be bought here. I shall be glad to purchase pearls for Dr. Jameson, if he will give me some idea what to get and how much to spend.”

I gladly availed myself of this offer, and asked Mr. Southwell to spend five pounds in the purchase of “cyst-pearls.” For this sum he procured from a local jeweller a parcel of 21 small “fine” pearls, which I received in February 1911.

* I must here incidentally refer to a quite erroneous interpretation which was placed upon the expression of my views as to the origin of the sac in *Mytilus* in my paper above referred to.

My account of the development of this sac on p. 149 appears to have been taken by Herdman and by Boutan (3 & 4) to imply that I thought the sac arose from the mesoblastic connective-tissue elements of the mantle. As I explained in a letter to Prof. Herdman, which he was good enough to publish, as showing my views, on p. 9 of Part V. of his Report, I never had any doubt that the sac was a true epidermis. What I wished in my paper to emphasize was that in *Mytilus* it appeared to arise independently of, and not in continuity with, the outer epidermal epithelium, perhaps from in-wandering epidermal cells, perhaps from more deeply seated elements of epiblastic origin, some of which (*e. g.* certain flask-shaped glands in *Margaritifera*, see Pl. XLI. fig. 33) appear to project below the basement-membrane. Had I dreamed that I should have been suspected of attempting to promulgate heretical views on the doctrine of the immutability of the three primary germinal layers, I would have been more cautious in the choice of my phrases. But even if my wording in that paper was unintentionally somewhat ambiguous, my *résumé* of my work in ‘Nature’ (26) should have cleared away any misconception, for in that paper I definitely stated (p. 280) that “a true pearl is laid down in a closed sac of the shell-secreting epithelium, embedded in the subepidermal tissue of the mantle and completely cut off from the outer epithelium itself. . . . Such a sac, with its contained pearl, may be compared to a human atheroma cyst.” I have not yet reached the stage at which I can add to what I said in 1902 about the actual mode of origin of the epidermal sac in *Mytilus*, but I hope before long to be able to contribute some more facts on the subject.

I then tried the Colombo Museum in the hope of getting some oysters with pearls *in situ*, but Dr. Pearson had no preserved material to spare. I tried to obtain material from Madras from Mr. Hornell, but he wrote me, in January 1911, that his own material was exhausted, and that he would not be able to obtain any more till the next inspection, a year later. However, H.H. the Jam Saheb of Nawanagar most kindly sent me some preserved specimens of this species with pearls *in situ* from the Gulf of Kutch, and I hope, in a later publication, to be able to put forward some observations on the actual process of pearl-production, based on these.

The following material was available for these investigations :—

(i.) Twenty-one pearls bought in Ceylon. It is, of course, possible, though not probable, that some of these originally came from elsewhere, *e. g.* the Persian Gulf *via* Bombay, but they, or at least the great majority of them, were certainly derived from *M. vulgaris*, the pearls of which have a characteristic colour and lustre quite different from that of the pearls found in *M. margaritifera* and *M. maxima*.

They were small "fine pearls," mostly spherical, a few oval or slightly lenticular. One was a brown pearl formed in the mantle-margin from the prismatic substance. They were all decalcified and examined whole, cleared in oil of cloves, and drawn. They were then sectioned (except in the case of three examples which were preserved whole). Their nuclei were in no cases Cestodes; they usually contained a cavity with a few granules surrounded by sphaerocrystal-like matter, allied to or identical with the "repair-substances" described below. In several cases, however, the actual nucleus was a grain of sand. These specimens are preserved as preparations XL, XLII, XLIII, XLIV, XLV, XLVII, LI, LII, LIII, LIV, LIV A, LIV B, LIV C, LIV D, LIV E, LIV F, LIV G, LIV H, LIV I, LIV J, and LIV K (Pls. XLI.-XLIII. figs. 35-45 and Pls. XLV., XLVI. figs. 50-57).

(ii.) *Dr. Kelaart's Material in the British Museum.*

In 1901, when I was investigating the origin of pearls in *Mytilus*, Mr. E. A. Smith, I.S.O., allowed me to examine five old specimens of the Ceylon Pearl-Oyster from Dr. Kelaart's collections in the British Museum. Mr. Smith very kindly allowed me to make further use of some of this material for the present investigations.

The specimens are labelled :—

- "1 specimen of pearls in ovaria,
- 3 specimens of pearls in mantle,
- 1 specimen of ova of Entozoa in liver of *Meleagrina margaritifera*."

The specimen with "pearls in ovaria" was a pearl-oyster with

a quantity of clustered pearls, mostly of the baroque and seed-pearl classes, in the visceral mass. The three examples with "pearls in mantle" showed pearls, chiefly in the regions of the levator muscles, though some were in the non-muscular parts of the visceral body-wall. The specimen with "ova of Entozoa in liver" is interesting, as showing the Cestode, *Tylocephalum ludificans*, in its whitish fibrous pearl-like cysts, which on superficial examination suggest "eggs." It was in this specimen, in 1901, prior to Prof. Herdman's departure for Ceylon, that I first became acquainted with these larvæ, which Prof. Herdman identified as the cause of cyst-pearls. The few observations that I was able to make at that time led me to the conclusion that there was no evidence that this parasite was concerned in pearl-formation*, a conclusion that I have, so far, seen no sufficient cause for modifying.

Owing to their age, the state of preservation of these specimens was naturally somewhat defective, and for real detailed histological work upon the pearl-producing tissues they were quite useless.

Many of the pearls in these specimens had fallen out of their sacs and lay in the bottom of the jar. Some of these, along with others picked out of the tissue, numbering 22 in all, were decalcified and examined in oil of cloves, and six of them were then sectioned and further examined. [Preparations XIV, XV, XVI, LXXI c, LXXI g, LXXI j (Pls. XXXVII., XXXVIII. figs. 16-18 and Pl. XLIV. figs. 46-48).]

A large piece of tissue in the wall of the visceral mass, measuring about $5 \times 5 \times 4$ mm., and containing no less than 16 pearls, was cut out from the specimen with "pearls in ovary," decalcified, stained with borax carmine and indigo carmine, and sectioned [Preparation XXVIII (Pl. XXXVII. figs. 14, 15)]. These pearls were all of the class which I refer to provisionally (see below) as muscle-pearls, and were mostly formed around central cavities.

(iii.) *Unlabelled Material in the British Museum.*

Mr. Smith also allowed me to examine two unlabelled specimens of *Margaritifera vulgaris* in the British Museum, the history of which is unknown. One of them was with the example in spirit now on show in the Museum, and was accompanied by its shell. It is from this example that preparations XXVII and XXIX were cut. It contained a large number of muscle-pearls and what Prof. Herdman calls "calcospherules" in the left mantle-lobe, and in the region of the adductor muscle on the left side. The other example had been removed from its shell. It contained a large number of clustered pearls, of all sizes, in the right mantle-lobe. The tubes in which the specimens were preserved contained also a lot of loose pearls which had dropped out of both these specimens.

* In 1902 (25), p. 149, I pointed out that Cestode larvæ were not surrounded by a pearl-sac.

From the first of these specimens the following preparations were made:—

(a) Preparation XXVII, a piece of tissue cut from the borderland between the mantle and the adductor in the first of the above specimens. This piece measured about $7 \times 5 \times 4$ mm., and contained 36 small pearls and numerous so-called "calcospherules." The preservation was so bad that no differential staining of the soft tissues could be obtained, all parts reacted alike to the stains used. [Preparation XXVII (Pls. XXXVIII., XXXIX. figs. 19–21, Pl. XL. figs. 24–27.)]

(b) Preparation XXIX was a piece of the mantle of the same individual near the margin, containing 17 so-called "calcospherules," one of which is becoming coated over with nacre (Pl. XXXIX. figs. 22 & 23). The figures were made from the whole object—fig. 22 representing it as it was before decalcification, fig. 23 after it had been decalcified; both as seen when cleared with oil of cloves. The preparation was then sectioned, but the state of preservation did not allow of the relations of the "calcospherules" to the tissues being investigated in this instance. A piece of tissue was also cut from the second of these specimens, decalcified, examined entire, and sectioned. It contained about 20 small pearls and numerous so-called "calcospherules." [Preparation XXIV.]

Forty pearls, of varying sizes, some lying loose in the bottoms of the jars containing the specimens, others taken from the tissues, were decalcified and examined in oil of cloves. Of these, six were sectioned and further examined. [Preparations XXIII, LXIII (A, B, & L), and LXVI (A & I) (Pls. XXXIX.–XLI. & XLIV. figs. 21 a, 28, 31, 32, 49).]

All the pearls from these specimens I refer to the class called by Herdman "Muscle-Pearls."

(iv.) *Three Specimens of the Pearl-Oyster collected by Professor Herdman in 1902.*

Prof. Herdman, at the request of the Ceylon Company of Pearl Fishers, Ltd., very kindly allowed me to examine his material (see (v.) below) and handed me three specimens of the Pearl-Oyster, each of which contained a small "muscle-pearl" at the point of insertion of one of the levators of the foot. The pieces of tissue containing these three pearls were cut out, decalcified, and sectioned [Preparations IV, VI, and VII (Pl. XXXV. fig. 8)]. Although these specimens had, apparently, been preserved in formalin, which is not the most satisfactory preservative for histological purposes, they showed quite a lot of histological detail, and enabled me to form some idea of the mode of origin of muscle-pearls, and of the curious cyst-like bodies which precede them.

(v.) *Professor Herdman's Slides.*

As stated above, Prof. Herdman very kindly allowed me to examine his slides, which he sent to me a few at a time.

Most of these slides were preparations showing the parasitic Cestodes in the tissues of the oyster, but there were also a number of preparations of pearls, sectioned *in situ* in the tissues, showing in all about 25 pearls, 21 of which showed their nuclei more or less distinctly. The nuclei of these pearls were of very different characters, but in no case could I identify a Cestode larva in the centre of a pearl.

(vi.) *Three Specimens from the Persian Gulf.*

In September 1903, Mr. J. Calcott Gaskin, Assistant Political Agent at Bahrein, Persian Gulf, sent me 32 specimens of *Margaritifera vulgaris* from Bahrein preserved in alcohol. Out of 20 of these that I opened, 3 contained pearls, which, from their position, could obviously be classified as "cyst-pearls" (Herdman). Two contained a single pearl each, that in the first being about 2.5 mm. in diameter, situate in the left mantle-lobe, above the anterior end of the attachment of the gills [Preparation LXIV A], that in the second [Preparation LXIV B] being about 1 mm. in diameter and situate in the body-wall over the stomach. The third specimen had two small pearls, about 2 mm. apart, in the wall of the visceral mass, away from all muscle-impressions [LXIV C]. All these pearls were decalcified *in situ* in the tissues and sectioned. Their centres are described below.

In addition to the above the following pearls were decalcified and examined. More detailed particulars are given under the descriptions of the centres of individual pearls, given below:—

(vii.) Dry unlabelled pearls, probably from Ceylon, in the British Museum, three examples were decalcified.

(viii.) Mixed lot of pearls; given to me by Mr. Max Mayer, mostly from *Margaritifera vulgaris*; 115 were decalcified, of these 8 were sectioned.

(ix.) A collection of pearls from the last Ceylon pearl fishery, given to me by Mr. E. Hopkins. Fifteen were decalcified, and four of these were sectioned.

(x.) A collection of pearl-oysters, with pearls *in situ*, from the Gulf of Kutch; these are referred to above. Up to the time of writing, 18 pearls from these specimens have been decalcified, and 13 of them sectioned.

(xi.) Two pearls from *Margaritifera vulgaris*, from the Mediterranean, given to me by Professor Raphael Dubois.

(xii.) Five pearls from *Margaritifera vulgaris*, from New Caledonia, given to me by Professor L. G. Seurat.

(xiii.) A pearl from *Margaritifera vulgaris*, from Madagascar, given to me by Professor Seurat.

(xiv.) Two pearls from *Margaritifera vulgaris*, from Papua, from the Imperial Institute.

(xv.) Twenty pearls from *Placuna placenta*, from Lake Talakalamam, Ceylon, from the Imperial Institute.

(xvi.) About a dozen pearls from *Margaritifera margaritifera* var. *cumingii*, from the Gambier Archipelago.

In the course of these observations, apart from studies on the structure and formation of pearls in other forms, 356 pearls derived, with perhaps a few exceptions, from *Margaritifera vulgaris*, chiefly from Ceylon, have been decalcified and examined, 175 of these having been studied in sections.

(8) METHODS.

For decalcification, whether the pearls were free or *in situ*, preserved in alcohol or dry, I found alcohol of about 50 per cent. strength, to which a few drops of nitric acid had been added, was the best. Of course, a preserved pearl never decalcifies as well as a fresh one. In the case of dry pearls, where only the nucleus and central parts are required for examination, it is often an advantage, during decalcification, to strip off the outer layers of conchyolin, thus facilitating the penetration of the reagent. Bubbles of carbon dioxide, generated in the process of decalcification between the conchyolin-layers, cause a great deal of trouble, especially in old dry pearls, where the conchyolin seems to be particularly leathery and impermeable. Such bubbles often greatly distort the normal structure of the pearl, as seen in section, by tearing the conchyolin-layers apart and causing great spaces between them. The most suitable reagent for expelling the bubbles is absolute alcohol, in which the decalcified pearl is placed for a few days. In some cases, however, it was necessary to extract the gas under an air-pump.

For staining decalcified pearls hæmatoxylin was used, also borax carmine. Sections of the pearls in the tissues were stained sometimes with borax carmine and picro-indigo-carmine*, sometimes with hæmatoxylin and eosin or orange, occasionally with other reagents.

(9) STRUCTURE OF THE SHELL-SUBSTANCES.

The shell of *Margaritifera* consists of the following parts:—

- (i.) the outermost layer or so-called Periostracum;
- (ii.) the prismatic layer, forming with (1) the “back” of the shell, the fragile, dark-coloured “lip,” and the lappet-like processes of the margin;

* Borax carmine (Grenacher's) in bulk:—

Picro-indigo-carmine as under, on the slide.

A. Saturated solution of picric acid in 90 per cent. alcohol.

B. Saturated solution of indigo-carmine (Grubler) in 70 per cent. alcohol.

1 part of A, 2 parts of B, 6 parts of 70 per cent. alcohol.

- (iii.) the Nacre or Mother-of-Pearl, forming the lining and the bulk of the shell ;
- (iv.) the Hypostracum, the substance to which the muscles are attached by a specialised epithelium ;
- (v.) the Hinge Ligament.

The mass of the shell is further divisible chemically and microscopically into an albuminoid substance called "conchyolin" and crystalline carbonate of lime deposited therein. Römer's careful observations (32) have shown beyond a doubt that there is a sharp separation between these two substances: the conchyolin forming an alveolar framework, in the chambers of which the salts are deposited; the structure of the calcium carbonate being crystalline, its form being determined by that of the spaces in which it is deposited.

The ratio of conchyolin to calcareous salts differs in different parts of the shell. Thus Römer (32) has found in *Margaritana*, the fresh-water pearl-mussel, that the organic substance constitutes 1.47 per cent. by weight of the prismatic substance, but only .64 per cent. of the nacre. This is most interesting as giving support to the theory of the present writer, enunciated below, that the different structures of the different forms of shell-building substances, normal and pathological, are in part a function of the proportions in which these two constituents are secreted by the tissues of the mollusc.

To turn now to the details of the structure of the several constituents of the shell.

(i.) *The Periostracum.*

The origin of the Periostracum can best be understood if we consider first those forms which live in fresh or estuarine water, or are otherwise subjected to conditions which render necessary a thick cuticle-like layer to defend them from the erosive action of organic acids derived from decomposing animal and vegetable matter (*e.g.* the Unionidæ and *Mytilus*). The periostracum in such cases has been described fully by several authors, *e.g.* Biedermann (1), Moynier de Villepoix (28), Tullberg (47), Ehrenbaum (9), Felix Müller (29), Stempell (44), List (27 b), etc.

In these cases the periostracum is composed of two constituents. The outermost layer is probably formed as a true cuticle directly by transformation or cuticularisation of the outer surfaces of the cells of a specialised epithelium in the inner (axial) face of a deep groove which runs along the mantle-margin, and which has been called by Moynier de Villepoix (28, p. 18) the "fente marginale." This marginal groove divides the mantle-margin into an inner and an outer lobe, the former being pigmented and sensory, the latter being a part of the shell-secreting apparatus. This outer

layer of the periostracum is closely adherent to the specialised epithelium, so that secondary thickening, if it takes place (and my own observations on *Mytilus* and *Modiola* lead me to think that it does so to some extent, a view which is held also by List, 27 b, p. 55), differs from that of all other parts of the shell (including the inner layers of the periostracum) in that it is secreted from outside or centrifugally with respect to the body of the animal and the shell, instead of from inside or centripetally. It would, indeed, seem as though there were morphological grounds for restricting the name periostracum to this particular layer of the outer cuticle-like substance, or, failing that, for introducing a term which would separate it more sharply from the more bulky inner layers. The structural distinctions of this layer are well shown by Römer (32) fig. 25 (*Margaritana*), by Moynier (28) fig. 50 (*Mytilus*), by Tullberg (47) Taf. iv. fig. 3 c, fig. 4 d (*Mytilus*), and by List (27 b) in the Mytilide generally.

The greater part of the periostracum, however, is laid down centripetally, layer upon layer, by the epithelium on the outer side of the marginal groove (*i. e.* on the inner side of the outer of the two lobes of the mantle-margin, Tullberg (47) p. 27). It is stratified, and in *Mytilus* contains, near its outer limit, a characteristic layer of large alveoli. The stratifications of this substance have been shown by Römer to correspond to layers of minute alveoli (32, fig. 25).

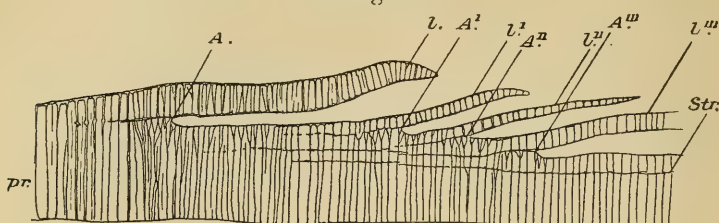
Internally the inner layers of the periostracum pass over into the conchyolin framework of the prismatic layer.

In some forms, e. g. *Anodonta*, the distinction between the two constituents of the periostracum are emphasized by the outer layer being much greater in area than the inner ones, and being thrown into folds upon which the inner layers lie unconformably.

The Mother-of-Pearl Oysters (together with such forms as *Ostrea* and *Pecten*) differ from the types to which the above description refers in the fineness of the periostracum and in having much more freely retractile mantle-margins. In sections of the decalcified shells of the Mother-of-Pearl Oysters it is difficult—indeed, I might say impossible—to differentiate the periostracum from the outer layer of the organic basis of the prismatic substance (text-fig. 35, p. 302; see also Pl. XXXIV. fig. 6). Here marginal growth proceeds by a series of steps and retreats, the free mantle-margin being retractile to the edge of the nacre, and being so retracted when the shell closes. Thus, after a new process of the lip has been formed, the mantle-margin is withdrawn, and forms a fresh attachment on the inner surface of the last-formed lip, from which a fresh lip is produced. So the periostracum of lip no. 2 is attached to and apparently a direct continuation of the inner surface of the conchyolin of the prismatic layer of lip no. 1, and constitutes the outer layer of the conchyolin of the prismatic layer of lip no. 2. But Herdman has shown that, difficult as it is to distinguish a separate periostracum in sections of the shell, such a layer, of extreme delicacy, does exist at the

margin, and arises in the normal manner in a marginal groove (Ceylon Report, Part II. Anatomy of Pearl-Oyster, plate viii. fig. 2).

Text-fig. 35.



Margaritifera vulgaris, Persian Gulf. Section through the lip of the shell, after decalcification, showing the successive lappet-like processes of the prismatic substance (L, L', L'', L'''). *pr.*, prismatic substance; *Str.*, stratification of same. A, A', A'', A''' , points marking the successive retreats of the secreting margin, which takes place when new lappets are to be formed. At these points the "periostracum" of the new lappet is continuous with, and indistinguishable from, the inner conchyolin-layer of the prismatic substance of the last-formed lappet. Preparation X ($\times 35$), see also Pl. XXXIV. fig. 6.

(ii.) *The Prismatic Substance.*

Reduced to its simplest terms the prismatic layer of the Mother-of-Pearl shell consists of prisms of calcium carbonate perpendicular to the surface of the shell, bounded externally and internally by membranes of conchyolin, which are connected by vertical membranes forming the septa between the prisms (text-figs. 35 and 36; see also Pl. XXXIV. figs. 6, 6 a; Pl. XL. fig. 29 a). Where interruptions in the continuity of the growth of this layer have occurred, the layer of prisms may be divided by one or more horizontal walls of conchyolin (text-figs. 35, *str.*, and 38, *str.*), which break up the prisms into segments, or which divide the layer into two or more series of prisms. The individual ends of the prisms in one layer do not of necessity coincide with those of the prisms in the next layer, though they frequently do coincide. The septa between the prisms may also show annular thickenings, corresponding to zones of constriction around the prisms (Pl. XXXIV. fig. 6 a, *ann.*). Römer has shown (32, p. 35) that the prisms of the pearl-shell (like those of *Pinna*, described by Biedermann (1), p. 9) behave between crossed nicols in the same manner as single crystals. The prisms differ enormously in size, according to the age of the oyster and the conditions under which they are secreted.

There is a sharp line of demarcation between the prismatic and the nacreous layers in *Margaritifera*, the innermost layer of the conchyolin of the former being connected to the outermost layer of that of the latter by a series of fine connectives of conchyolin (Pl. XXXIV. fig. 6 a, *con.*), forming a curious alveolar layer.

The prismatic substance is secreted by that part of the epidermis apposed to the inner surface of the shell which is nearest to the margin of the mantle, and it is clear from the rapidity with which the columnar lip and its lappet-like processes are regenerated when injured and are added to in growing young shells that the characters of this layer are associated with relatively rapid secretion. This is significant, in view of the resemblance of this layer to some of the rapidly secreted repair-substances which replace the nacre under certain abnormal conditions (see below).

Römer's work (p. 18) gives an interpretation of the nature of the prisms, which I have found most useful in helping me to interpret my own observations on pearl-formation. According to this hypothesis, which was suggested to Römer by my illustrious teacher, Prof. Bütschli, each prism is an incomplete sphaerocrystal, the growth of which has been arrested in all directions but one, viz. the direction from which the new shell-substance is secreted. Römer says (p. 18):—

“Dass diese Sphärokristalle der einzelnen Prismen so unvollständig ausgebildet sind, rührt daher, dass gleichzeitig und dicht nebeneinander die Anfänge der einzelnen Prismen oder Spärokristalle gebildet wurden, die bald seitlich aufeinander stiessen und sich so gegenseitig in der weiteren Ausbildung hemmten; nur an ihren inneren Enden vermochten sie einseitig weiter zu wachsen”*.

If I may be allowed to state the proposition in slightly different terms, the prismatic shell-substance (and, indeed, if my interpretation of the variations of the nacre, normal and pathological, are correct, the whole of the shell-substance) agrees with a sphaerocrystal in that it is composed of crystalline or crystallised substance which can only grow by the apposition of fresh layers deposited on a single surface, owing to the matter in solution only having access to one surface of the crystalline mass. When this surface is the outer surface of a sphere, a body with more or less of the characters of a sphaerocrystal results (*e. g.* Harting's bodies and Pearls); where it is approximately a plane surface, as in the growth of the Molluscan shell, a structure such as the

* Bütschli in 1908 (6, p. 26) explained his definition of “sphaerocrystals,” more especially with reference to the crystal-like prisms of *Pincta* (and by analogy of *Margaritifera*), as follows:—

“Wie aus den Darlegungen in meinem Werk von 1898 hervorgeht, verstehe ich unter einen solchen nicht ein Aggregat zentrisch angeordneter Kristallnadeln oder Einzelkristalle, was zwar die übliche Anschauung ist, sondern ein einheitliches Kristallgebilde, in welchem die besonderen feinsten Strukturverhältnisse, die auch den gewöhnlichen Kristallen ihre charakteristischen Eigenschaften verleihen, nicht entsprechend einer Axe, sondern um ein Zentrum radiär orientiert sind. Wenn daher der Radius eines solchen Sphärokristalls sehr gross wird, und man ein radiales Stück desselben, weit entfernt von dem Zentrum, herauschneidet—und so verhalten sich etwa die Pinnaprismen—so muss dieses Stück sich natürlich wie ein gewöhnlicher Kristall verhalten; obgleich die von mir gegebene Zurückführung auf einen Sphärokristall mit grossem Radius ganz zutreffend ist.”

Molluscan shell results, the axes of its constituent elements being approximately parallel.

(iii.) *The Nacre.*

This substance, which forms the bulk of the shell, and gives the shells of the genus *Margaritifera* their commercial value as Mother-of-Pearl, and the pearls their beauty, is stratified, and in it the calcium carbonate is divided into extremely minute bodies in the organic network. It is secreted by the outer surface of the mantle and body-wall.

I will not attempt here to review the many writings on the structure of this layer. I can at present add little to the recent work of Römer (32), who has studied its structure and that of its decalcified conchyolin framework very thoroughly. The organic basis which gives it its form, and which retains its iridescence after the calcareous salts have been extracted, consists of a series of parallel lamellæ, of extreme fineness, united to one another at intervals by radial connections, so as to form a series of minute flat or lenticular chambers, separated by organic walls of extreme delicacy. The calcium carbonate appears to be enclosed in these chambers in the form of little polygonal plates or lozenges. This structure is difficult to observe, owing to the distorting effect of the decalcification process, which, owing to the evolution of gas-bubbles, tears some lamellæ apart and forces others tightly together. It becomes much more obvious in some of the abnormal and pathological varieties of nacre described as "repair-substance" below, notably in "granular repair-nacre."

I believe that the lustre (not the iridescence) of mother-of-pearl, and of pearls, is in great measure due to the fact that each of these tiny plates is a minute, biconvex lens; and that the extraordinary and indescribable character of the light reflected from the surface of a fine pearl is in part the cumulative expression of the action of these myriads of little lenses upon the light reflected from the surfaces of calcium carbonate and of conchyolin which underlie them.

(iv.) *Hypostracum, or Muscle-Attachment Substance.*

This curious substance has not secured all the attention it deserves. It has been described by several writers under the names Hypostracum (Thiele, 46), Stäbchenschicht (F. Müller, 29), durchsichtige Substanz (Ehrenbaum, 9; Tullberg, 47).

I retain the name hypostracum, as emphasizing the distinct origin and characters of this layer, and as shorter and more convenient than "durchsichtige Substanz."

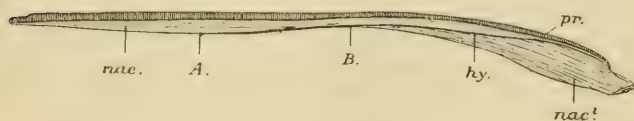
This hypostracum is a fine columnar layer forming the surfaces where the muscles are inserted into the shell (Pl. XXXIV. figs. 5 & 7, *hy.*; text-figs. 36 & 37).

It is more transparent than the nacre—indeed, the iridescence and lustre of the muscle-scar is due to the nacre lying below and

shining through this "durchsichtige Substanz," the substance itself not possessing the structure to which these optical properties are due.

It is composed of columnar or fibrocrystalline needles of carbonate of lime (Stäbchenschicht, Müller), but shows in places, in addition to its columnar structure, a distinct stratification parallel to the surface; this is seen also in the basis which remains on decalcification (Pl. XXXIV. fig. 5). I attribute this stratification to variations in the organic basis, which are probably independent of the form and structure of the crystalline needles. Hypostracum only occurs where the specialised muscle-attachment epithelium is inserted into the shell, and, as the muscles move away from the umbonal region with the growth of the shell, it is quickly covered over by ordinary nacre which is deposited in the wake of the advancing muscle. In a section of the shell from the umbo through the adductor scar the hypostracum layer can be traced across the shell through the nacre from the scar to the umbo, the thickness of the overlying nacre increasing as the umbo is approached. By means of this hypostracum layer, the wandering of the adductor muscle is recorded in the shell-substance (text-fig. 36, *hy.*).

Text-fig. 36.

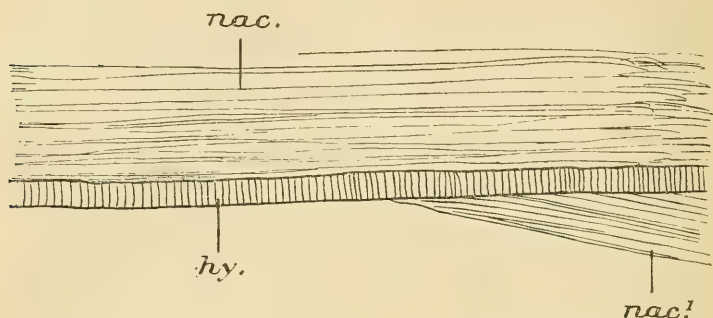


Margaritifera maxima Jameson. A young shell or "chicken shell" from Port Darwin, Northern Territory of Australia (London markets). Section from the umbo to the shell-margin passing through the middle of the adductor impression. *pr.*, prismatic layer; A-B, muscle-scar, covered with "Hypostracum"; *hy.*, the hypostracum layer, by means of which the migration of the muscle, from what is now the umbonal region, with the growth of the shell can be traced; *nac.*, nacre of the shell-margin, formed external to the muscle-scar; *nac'*, nacre of the thick subumbonal region, deposited internally to the hypostracum. Two-thirds of natural size.

In the shell figured, a young example of the large white Australian Mother-of-Pearl shell (*M. maxima* Jameson), the hypostracum is 18–20 μ thick over the muscle-scar, thinning out to 10 μ and then to 4 or 5 μ at the extreme outer edge of the scar, where the muscle has most recently made attachment. As this layer is traced backwards towards the umbo, through the nacre, it is found to get gradually thinner, just as the prismatic substance (which in this shell is about 1 mm. thick in the region of the adductor scar, and in the lip of very old examples of the same species may be 2 or 3 mm. in thickness) is found to get thinner towards the umbonal region. These differences are no doubt associated with the relative ages and sizes of the animal at

the respective periods, and with the relative rapidity of peripheral growth in young and older oysters. Text-fig. 37 shows the hypostracum of the same example (*M. maxima*) enlarged forty times.

Text-fig. 37.



The inner limit of the adductor scar, in the same shell as that shown in text-fig. 36. *hy.*, hypostracum; *nac.*, nacre external to same; *nac.!*, nacre internal to same. $\times 40$.

Exactly the same relations occur in *M. vulgaris*, a section through the umbonal side of the adductor scar of which is shown in Pl. XXXIV. fig. 7. But in this example, an old thick Lingah shell from the Persian Gulf, in which, in all probability, peripheral growth, and consequently the wandering of the muscle, had ceased, the hypostracum is thicker, measuring $130\ \mu$ in thickness.

The hypostracum undergoes but little secondary thickening, compared with the nacre. Hence, in thick massive shells like *M. maxima*, where the newly forming nacre in the umbonal region and also towards the lip and around the muscle-scar outstrips the hypostracum in development, the muscle-scar is the thinnest part of the entire shell, except the extreme edge. This is well seen in text-fig. 36, in which figure the area between A and B represents the muscle-impression, but it is even more obvious in older thicker shells. Some interstratification of hypostracum and nacre occurs at the borders of the muscle-scars, where changes in the outline of the muscle have taken place. This is figured by Tullberg in *Mytilus* (47, Taf. v. fig. 2). The same is shown for *Margaritifera vulgaris* at *hy.*', *hy.*'', in Pl. XXXIV. fig. 7. Felix Müller (29, Taf. xxix. fig. 13 b) shows the lateral transition of this substance into nacre. I have observed the same thing in some of the "Muscle-Pearls" described below.

When decalcified the hypostracum leaves behind it an organic basis, which is somewhat different from the conchyolin of the rest of the shell in its reaction towards stains. This is of interest in connection with the view generally held that this layer, unlike the other calcareous parts of the shell, which are probably

due to simple secretion, arises by a gradual transformation into shell-substance of the outer regions of the specialised epidermal cells which underlie it, *i. e.* in the same manner as the Crustacean carapace and the outermost layer of the periostracum. It shows a well-marked striation perpendicular to the surface, the striae no doubt corresponding to the outlines of the spaces which were occupied by the needle-like fibrocrystalline bodies of calcium carbonate, and also at times indistinct lines parallel to the surface (Pl. XXXIV. fig. 5). In sections in the plane parallel to the surface this substance shows an alveolar structure. It sometimes shows a tendency to break up into segments, corresponding to the underlying epithelium-cells (Pl. XXXIV. fig. 5, *hy.*).

(v.) *Hinge-Ligament.*

I do not propose to discuss the hinge-ligament here, as it has not the same direct bearing on the question of pearl-formation as the above layers, though leathery pearls, composed of this substance, are sometimes found (e. g. in *M. maxima* in Australia).

(10) THE SHELL-SECRETING EPITHELIA.

The ordinary shell-secreting epidermis of *M. vulgaris*, so far as I have been able to study it in the unsatisfactory material available, consists of columnar or tessellated cells (Pl. XXXV. fig. 8, *ep.*; fig. 9, *o.ep.*; Pl. XXXVI. fig. 11, *o.ep.*; Pl. XLI. fig. 33, *ep.*), brick-shaped or palisade-like, according to the degree of contraction, in sections perpendicular to the surface, with a certain and variable number of goblet- and gland-cells. The nuclei of the epidermal cells are oval or spindle-shaped. These cells are attached to the subjacent tissues by a basement-membrane of delicate fibrillæ which distinctly marks the boundary between the epidermal epithelium and the subjacent tissues. Beneath this epidermis is a characteristic granular parenchyma (Pl. XXXV. figs. 8 & 9; Pl. XXXVI. figs. 10 & 11; Pl. XXXVII. fig. 14; Pl. XLI. fig. 33, *par.*), which contains a great variety of elements, some being comparable to the "Rundzellen" and "Langer'schen Blasen" described by List (27 *b*) for the Mytilidæ, some being dark-staining, apparently glandular elements that open out between the epithelial cells (fig. 33, *gl.*). As observed by List (27 *b*), this epithelium and the underlying tissues are excessively variable in their characters.

Over the surface of the muscle-attachment the epidermis is different (Pl. XXXIII. figs. 4, 4 *a*; Pl. XXXV. fig. 8, *m.ep.*). Here it consists of columnar cells, usually about 10–12 μ long and 2–4 μ broad, which pass over basally without any distinct dividing-line into the muscle-fibres. Whether the transition is direct, or whether in fact a connective-tissue junction is present, cannot be determined from the available preparations of *Margaritifera vulgaris*; but in *Mytilus edulis* there is a distinct connective-tissue layer (fig. 5, *c.t.*), the fibres of which,

continuous with the bases of the epidermal cells, are attached to the ends of the muscle-fibres (*musc.*), which may be produced out into tails. Tullberg recognised that such a junction was present. In *Margaritifera vulgaris* the attachment epithelium-cells may have one or several tails, probably also of connective-tissue character, passing over into as many muscle-fibres.

Distally these epidermal cells broaden out somewhat, ending in a clean-cut surface, which may be represented in section by a clear zone forming a slightly acute angle with the sides. The nuclei, which are oval and about 3-4 μ long, are situated in the middle of their length.

It is possible to make out, in some cases, a striation of these cells in the direction of their long axes. Occasionally the distal surface is raised into processes and papillæ, but this may well be a result of imperfect fixation of the tissues.

These cells stand out as stiff, independent, almost bristle-like entities, and are probably hard and tendinous in character. They are frequently preserved in old preparations in which all traces of the structure of the ordinary epithelia have disappeared. In some cases they seem to have been drawn out in the fixing process; thus the longest cell shown in Pl. XXXIII. fig. 4 *a* measured 26 μ . It seems possible that in the shrinkage consequent upon fixation the majority of the elements here had broken away from the shell, but that this particular cell had remained attached and was consequently fixed in a state of extension. This figure shows that the connective-tissue elements extend up between the bases of these cells.

This epidermis is very closely adherent to the specialised shell-layer (hypostracum) to which it is attached, and the connection seems to be between the cells and the organic basis of the shell. Thus, in decalcifying a piece of the shell of *Mytilus* with the adductor muscle attached, the hypostracum remained adherent to the epithelium and tore away from the rest of the shell (Pl. XXXIV. fig. 5).

(11) SHELL-SECRETION.

I will not attempt to survey the writings of previous investigators on this subject. This has been ably done by Stempell (45), whose review contains a full and lucid discussion of the question.

The general trend of opinion now seems to favour the theory dating back to Reaumer, 1709 (31), and held by Tullberg, Ehrenbaum, Moynier de Villepoix, and the majority of recent French and German investigators, that the shell (except the outermost layer of the periostracum and the hypostracum) is formed from a fluid secretion, rather than the theory specially associated with Huxley's name (24) that the shell is derived from a succession of fully developed skins or cuticles, shed as membranes by the underlying epidermis.

The outermost layer of the periostracum (which in *Margaritifera* is a negligible quantity) and the hypostracum probably arise by direct transformation of the outermost portions of specialised epidermal cells, and on this account it may prove necessary to draw a sharper morphological distinction between them and the rest of the shell than has hitherto been done*.

The prismatic layer and the nacre, together with the inner layers of the periostracum, more probably arise as a secretion which first hardens into a membrane *in situ*, and then forms the delicate skin which Huxley observed between the mantle and the shell in the freshwater mussels.

It would appear that the lime-salts and albuminous fluid which hardens to form the conchyolin are independent of each other, and may be secreted in varying proportions. Where these two constituents are secreted under circumstances which inhibit the control of the shell-secreting epidermis, or where the secretion takes place so copiously and rapidly that the epidermis is unable to regulate the deposition (as in the pathological cases described below), lime-salts are precipitated in a columnar form, much as in Harting's bodies, and, concurrently with this, the albuminous fluid is transformed into an insoluble substance resembling conchyolin. The process of shell-secretion at the rapidly growing edge of the shell resulting in the formation of the prismatic layer—which in *Margaritifera vulgaris* measures as much as 1 mm. or more in thickness—is probably in some degree analogous to the process of secretion of repair-substance, the epithelium exercising comparatively little control over the arrangement of the elements.

But in the case of the nacre it is different. Here the epithelium seems to exert a definite and very strict selective influence resulting in the finely stratified and chambered structure which can, I think, best be interpreted as arising from rhythmically intermittent secretory action on the part of the controlling epidermis. Any disturbance of the normal rhythm of this secretion, *e. g.* the stimulation of an intrusive particle between shell and epidermis, results in the formation of the irregular substances described below, such as granular repair-nacre, the several varieties of columnar repair-substance, or the amorphous non-calcified substance.

It would thus seem as though the structure of the shell-substance, and its variations, normal and pathological, could be expressed in terms of the proportions of lime-salts and organic

* The difference between the outermost layer of the periostracum and the hypostracum on the one hand, and the remainder of the shell on the other, the former parts arising by direct cell-transformation or cuticularisation of cell-protoplasm, the latter as a secretion poured out by the cells, suggests a line of inquiry that might yield interesting results. Can these two constituents of the shell be separated morphologically and phylogenetically, and, if so, can the former be regarded as in any sense homologous with the cuticular exoskeleton of an ancestor common to Mollusca and Arthropoda, the latter being a subsequent addition peculiar to the Mollusca, associated with their more sedentary modes of life, which has now, for all practical purposes, replaced the more strictly cuticular element as an exoskeleton?

salts secreted and of the periodicity of the secretion as determined by the control, or loss of control, of the secreting epidermis.

In fact, if my interpretation is correct, the processes involved in the building of the shell are the usual chemico-physical ones which govern crystallisation in colloidal media* controlled and limited by the time-factor which is a function of the activity of the living cells.

It is less easy to imagine the conditions which determine the transformation of the fluid albuminous secretion into the leathery conchyolin. One is naturally tempted to postulate a chemical transformation as a direct or indirect result of the action of nascent CaCO_3 , as in the case of the calcoglobulin in Harting's bodies (12); but the formation of this substance apart from the lime-salts, *e.g.* in the inner layers of the periostracum and in amorphous repair-substance, and in the case of shells grown in lime-free media (Moynier de Villepoix, 28, p. 122), seems to negative this; and it may well be that this change to an insoluble albuminoid is directly brought about by the action of the secreting cells themselves, or follows from the chemical composition of the secretion as shed.

(12) ABNORMAL AND PATHOLOGICAL PHASES OF THE SHELL-SUBSTANCE.

For a study of the beginnings of Ceylon pearls, a consideration of the variations in the shell-substance, when it is secreted under abnormal conditions, either on the surface of the shell or of a growing pearl, is of importance.

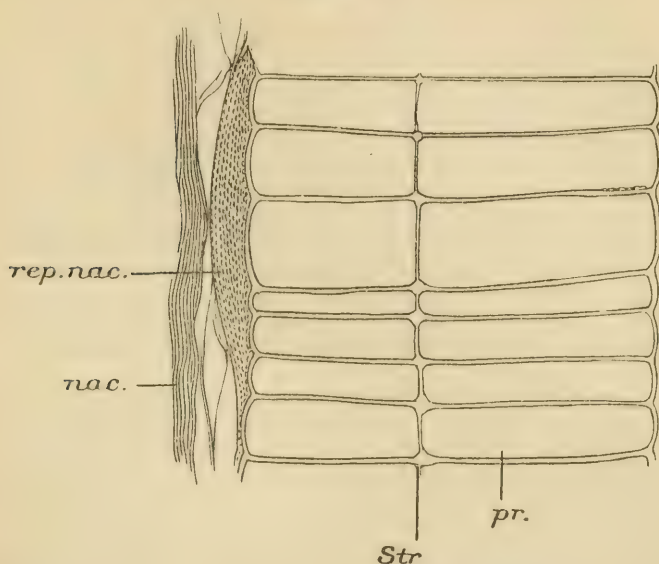
Where the normal rhythm of the process of shell-secretion is interrupted, *e.g.* by injury to the shell, or the intrusion between the epithelium and the nacre of a foreign particle or by other disturbances less easy to explain, certain irregularities in the process of secretion occur, resulting in an altered product.

In the simplest case such a disturbance results in a modification producing a granular appearance of the conchyolin-layers of the nacre. This modified substance I propose to call "granular repair-nacre." In sections made through this substance, after decalcification, the normal stratification is obscured by a highly granular appearance which seems to be due to an infinite number of connections between the successive conchyolin-layers resulting in a distinctly alveolar membrane. This is shown in text-fig. 38 (*rep.nac.*), which is taken from an artificial "blister" produced by the writer in *Margaritifera margaritifera* after the "Linnaeus" method, in British New Guinea in 1899. The foreign body was inserted near the mantle-margin, and the mantle secreted first a double layer of the prismatic substance,

* Biedermann (2), p. 171, recognises that the structure of the shell is essentially reducible to crystallisation processes, the influence of the cells being limited to the composition of the fluid, and perhaps the orientation of the primary centres of crystallisation. But I would add to these influences the periodicity of their action.

and then nacre, which, at places, showed the characters of "granular repair-nacre."

Text-fig. 38.



Margaritifera margaritifera Linnaeus (Black-lipped Mother-of-Pearl Oyster). Part of an artificially produced blister. *pr.*, prismatic layer; *Str.*, horizontal dividing membrane of concholin in same; *nac.*, nacre; *rep.nac.*, granular repair-nacre. (Preparation VIII.)

Pl. XL. fig. 29, from the "repair-membrane" formed by *M. vulgaris* over a hole in the shell (umbonal region), shows the same substance at *tr.* passing over on the one hand into columnar repair-substance, on the other into nacre. The same substance is seen at *tr.*

Pl. XLJ. fig. 30 (*rep.nac.*) shows the same substance, secreted at the point of junction of two pearls (from one of Dr. Kelaart's specimens of *M. vulgaris*). Here it was secreted as a result of disturbances following upon the fusion of the two pearls and the absorption or calcification of the intervening tissues. The granular repair-nacre in the preparation shows in places a distinctly columnar structure, indicating a transition to the columnar repair-substance; such a transition is still more obvious in Pl. XL. fig. 29.

The same granular repair-nacre is seen in Pl. XXXV. fig. 9, Pl. XXXVII. fig. 15, and Pl. XXXVIII. fig. 18, surrounding the central cavities of "muscle-pearls," where unduly rapid secretion might well be expected, and in Pl. XXXIX. fig. 23, where a hypostracum-pearl ("calcospherule," Herdman) is in process

of being coated over with nacre. The same substance is well shown in Pl. XLI. fig. 35 and Pl. XLIII. fig. 43 (*gr.*). In the last-named case it is seen to pass over on the one hand into nacre, on the other into columnar and amorphous repair-substances.

The next form of repair-substance is much more variable, and occurs in several distinct, though intergrading forms. I propose to call this "columnar repair-substance," in view of the calcium carbonate being crystallised in columns.

Columnar substance resembles, more or less, the prismatic layer of the shell—indeed, it is probable that Rubbel (33, p. 171) had a substance analogous to this columnar substance before him when he stated that the outer epithelium of the mantle of *Margaritana* is capable, in repairing the shell, of producing the prismatic substance which is normally only the product of the mantle-margin. (In the same way, he treats as "periostacum" the non-calcified material secreted under similar conditions, which I describe below as "amorphous repair-substance".) *

In its simplest form columnar repair-substance consists of parallel needle-like rods of carbonate of lime (which Steinmann (43), speaking of Harting's bodies, has aptly called "fibro-crystalline") deposited in an organic conchyolin-matrix, which, when the calcium carbonate is removed by acids, and a section is cut at right angles to the surface, presents a palisade-like appearance, due to the septa of conchyolin between the calcareous rods (Pl. XL. fig. 29; Pl. XLI. fig. 30, *col.*). In horizontal section this conchyolin has a honeycomb-like structure.

All kinds of variations occur in the coarseness or fineness of the calcareous elements and the organic framework.

This substance is frequently formed on the surface of the shell or of a pearl when disturbances arise in the rhythm of shell-secretion. In Pl. XL. fig. 29 it is seen in the repair-membrane formed over an injury caused to the shell by a boring parasite. In Pl. XLI. fig. 30 it is seen (*col.*) in the angle between the surfaces of two pearls which have become secondarily attached together.

Pl. XLI. fig. 31 shows the same substance developed under conditions similar to those existing in fig. 30. This figure is a drawing of a section through the suture between two pearls which have become secondarily fused together. The pearls themselves, with the intervening suture, are shown in Pl. XLIV. fig. 49; the end of the suture, where the curvatures of the two pearls diverge, in fig. 31. In the entire object, examined in oil of cloves (fig. 49), the suture was represented by a yellowish-brown line, the colour being due to the dead remains of the cellular membrane which originally separated the two pearls.

* While these substances are perhaps not strictly separable respectively on chemical and physiological grounds, I think it is well on morphological and pathological grounds to emphasize the distinction.

The membrane consisted of the lining epithelia of the two sacs, and a layer of parenchymatous tissue between these two epithelia.

The epithelia, and even the individual cells of the parenchyma, can be detected in some places (Pl. XLI. fig. 32).

If we try to trace the steps resulting in the condition figured on Pl. XLIV. fig. 49 and on Pl. XLI. fig. 31 (*i.e.* to survey the story of the formation of a double pearl), we may assume that they were as follows. As the two neighbouring pearls, each enclosed in a sac, grew in size, by the addition of fresh layers, they exerted a pressure on the intervening tissues, resulting in reduced circulation and consequent malnutrition which began at the first point of contact and extended outwards. Thus the contiguous surfaces tended to become flattened (fig. 49), and the intervening tissue, consisting of the epithelia of the two pearlsacs and a small amount of connective-tissue between them, finally ceased to be functional, died, and was preserved as a yellow membrane (Pl. XLI. fig. 32). At the periphery of the area of contact, where the curvatures of the two pearls diverged and were separated by a wedge-shaped plug of tissue, nacre-secretion continued longer, the last efforts of the epithelia being represented by *nac.* and *nac.'* in fig. 31. Finally, the epithelium ceased to control the deposition of its secretion, and, with the shrinkage of the atrophied tissues a space occurred on each side between the nacre and the epithelium, into which an extravasation of organic matter and salts occurred. The salts precipitated themselves in the form of columns or raphides with their bases apparently in or on the epithelia, and concurrently with this precipitation the soluble organic substance became converted into the conchyolin framework between the prisms, analogous to the "calcoglobulin" framework of Harting's bodies, derived from egg-albumen when calcium carbonate is precipitated in it. Lastly, the epithelia and intervening connective-tissue died and probably underwent irregular calcification, breaking away from the still functional tissues and becoming incorporated in the substance of the pearl. The still functional tissues now formed a single sac surrounding the two pearls, and quickly enveloped them both in a common nacreous covering.

Similar processes can be postulated to account for the condition shown in Pl. XLI. fig. 30. Here, between the curvatures of the surfaces of the two contiguous pearls, there was a triangular plug of tissue, which for some time remained attached to the degenerated membrane which separated the pearls. Its epithelium gave rise before it broke away to granular repair-nacre (*rep.nac.*) on the right, where the disturbance was presumably least, and to a small amount of columnar repair-substance (*col.*) on the left. Then it broke away from the degenerated and dead membrane between the pearls and retreated rapidly, exuding as it went the albuminous fluid, which, being secreted at a much greater rate than the lime-salts, was practically devoid of lime

and formed coarsely stratified amorphous substance (*am.*), broken by cleft-like cavities. Later on, when the retreat of the plug of tissue was less rapid, this amorphous substance passed over into columnar substance (*tr.*) and granular repair-nacre (*tr.*), and finally gave place to the nacre (*nac.*) of the common investment of the compound pearl.

The columnar repair-substance varies enormously, and passes over imperceptibly into "amorphous substance" or lime-free conchyolin, granular repair-nacre, ordinary nacre, and the prismatic substance of the shell. For example, the repair-membrane, a part of which is shown in Pl. XL. fig. 29, showed an immense number of variations from place to place. In some parts a second layer of amorphous substance was interpolated between the columnar layers; in others the columnar substance passed over into a coarsely alveolar substance with irregular cavities, some of which penetrated into the amorphous substance. In yet other spots the amorphous substance passed over through granular repair-substance into nacre.

Columnar substance is frequently stratified, consisting of a number of consecutive layers. This is seen at *col.* in the repair-membrane figured at fig. 29. It is also shown in the pseudo-nucleus of the pearl shown on Pl. XL. fig. 28 and Pl. XLIV. fig. 49, and in the pearls from the Persian Gulf in Pl. XII. figs. 33 & 34. In the former of these last-named instances it occurs immediately around the central cavity, in the latter case interstratified and intergrading with the nacre.

In Pl. XLIII. fig. 43 (*col.*) it is seen passing over on the one hand into granular repair-nacre, on the other into amorphous repair-substance. The same stratified columnar substance is well shown in Pl. XLV. fig. 51, where it forms a curious flaw running through the substance of a pearl.

Apart from this direct stratification, the columnar repair-substance may have an internal alveolar structure such as is shown in Pl. XLII. figs. 36, 37, & 38. Figs. 40-42 on the same Plate, taken from the pearl shown in Pl. XLVI. fig. 57 (a brown pearl composed of prismatic shell-substance), show the transition from amorphous repair-substance to columnar repair-substance (figs. 41, 42, *col.*), and from the latter to the prismatic layer of the shell (fig. 42, *pr.*).

The third variety of repair-substance I call amorphous repair-substance. In its typical form this substance is seen at *am.* in Pl. XL. fig. 29, where it is obviously the result of the first effort of the mollusc to close the injury to the shell, and in Pl. XLI. fig. 30, where it is the product of a fully functional epithelium, retreating rapidly and leaving its secretion in its wake. It shows little or no structure under ordinary magnifications, but is usually faintly stratified. It may contain cavities, arranged in rows parallel to the secreting-surface, and with at times also a radial arrangement. These cavities typically contain carbonate of lime. Pl. XL. fig. 29 *a* (*Margaritifera vulgaris*, Lingah Shell, Persian

Gulf) shows this substance formed as the first step in the development of a new layer of prismatic substance to cover over the tube of the worm *Leucodore*, which has entered between the mantle-margin and the shell, as is its wont. Here the mantle-margin, reacting to the stimulation of the parasite, has retreated and secreted a new "lip" to exclude it. This lip, like the normal lip, consists of the prismatic layer of the shell, but the irregularly secreted first layers of it consist of amorphous substance, containing alveoli in which a scanty supply of calcium carbonate was deposited.

The amorphous substance frequently occurs in the centres and around the central cavities of pearls, where it doubtless represents the first matter which the mollusc shed into the cavity. It probably corresponds to the "Theile des Schalenepidermis" recognised by von Hessling (18, p. 313) in the nuclei of pearls, and the "Kern von Chitinsubstanz" referred to by Pagenstecher (30, p. 502), and perhaps to the "Gelbbrauner Substanz" of Rubbel (34, p. 412).

The amorphous substance shows little receptivity to stains. It passes over sometimes into columnar substance (Pl. XLI. fig. 30, *tr.*), sometimes into granular repair-substance (Pl. XL. fig. 29, *tr.*, *tr.*'; Pl. XLI. fig. 30, *tr.*'). It also sometimes intergrades with a substance resembling the prismatic layer (Pl. XLII. fig. 41). Similar intergradations with prismatic substance were shown in some parts of the preparation from which Pl. XL. fig. 29*a* is drawn. Pl. XLII. figs. 40-42 are of interest as showing all manners of intergradations between amorphous, columnar, and prismatic substances, the different structures shown being apparently mainly dependent upon the proportions of calcium carbonate present. Thus we have in this pearl, which, owing to the impermeability of the amorphous substance, was imperfectly decalcified, tracing the layers from inside outwards: (1) a plug of nuclear matter of doubtful origin containing well-marked crystals (fig. 40, *nu.*)—these are true crystals (rhombohedra); (2) a layer of amorphous substance, passing over into typical simple columnar repair-substance (fig. 40, *col.*); (3) numerous layers of amorphous substance (figs. 40, 41, *am.*), some layers being quite lime-free, some having scattered alveoli containing calcium carbonate, some showing their cavities in radial rows, leading up, by transitions, to regular columnar substance (figs. 41, 42, *col.*), which differs from the prismatic substance proper (fig. 42, *pr.*) only in the smaller diameters of its constituent elements, a difference which, in view of the variability of the sizes of the prisms in the shell itself, is comparatively unimportant.

Again, the transition from the abnormal repair-substances to nacre in the pearl shown in Pl. XLV. fig. 52, *col.*, and Pl. XLII. fig. 36, *col.*, is equally striking. This is shown in detail in Pl. XLIII. fig. 43. At *nu.* is the outer wall of the sphaerocrystalline or columnar pseudo-nucleus of the pearl. At *nac.* is

shown the normal nacre of the pearl. The first-formed layers of nacre are incomplete, passing over into this area of repair-substance, and all stages of transition may be seen, corresponding to the gradually increasing control exercised by the secreting epithelium.

At first, amorphous substance (*am.*), alveolar in places, was secreted, no doubt with irregular crystallised bodies in the alveoli, some of which are actually preserved in the preparation, owing to incomplete decalcification. Peripherally this gave place to columnar substance (*col.*), which acquired a finely alveolar structure, and passed over, through granular repair-nacre (*gr.*), into normal nacre (*nac.*'), the layers of the concholin of which gradually merge into the horizontal markings of the granular substance. The amorphous substance in this preparation varies from layer to layer in the degree to which it is alveolar; at some places it might better be described as coarsely columnar substance.

Amorphous substance seems to be the first product where the shell is perforated and the mantle makes a sudden effort to close an opening to the exterior. In such cases it may be secreted so copiously that a tough leathery skin results, with little or no lime-salts in it (Pl. XL. fig. 29, *am.*). It is likewise secreted in layers when a break occurs in the nacre-secretion of a pearl or of the shell, owing to a pathological extravasation of cellular matter (Pl. XXXVIII. fig. 17, *am.*, *am.*'). These facts suggest that the organic basis of the shell is the constituent the secretion of which varies in quantity, the secreting-tissues (perhaps the granular subepithelial parenchyma in *Margaritifera*) containing a reserve of this material which can be poured out profusely when the shell is injured. It would seem that the lime-salts, on the other hand, are secreted more regularly, so that the mechanism for furnishing these cannot keep pace with that which yields the organic substance when the latter is called upon to make a special effort to repair damage. The resemblance of the inner layers of the periostracum (in forms with a thick periostracum) to amorphous repair-substance may perhaps be explained by postulating the absence or inhibition of the lime-secreting mechanism in the underlying tissues.

That the secretion of calcium carbonate could not keep pace with that of the organic substance, when the latter is produced in large quantities, is easy to understand in view of the very small proportion of CaO in the blood of Mollusca, and indeed of all invertebrates that have been investigated. According to Griffiths (quoted by Bütschli, 6, p. 62), the CaO in the blood of a number of bivalves examined varied from 0.032 per cent. in *Anodonta* to 0.067 per cent. in *Mytilus*.

Amorphous substance is seen in the pseudo-nuclei of pearls in Pl. XXXIX. figs. 20 & 21, and Pl. XL. figs. 24, 26, & 27; figs. 20, 24, & 27 showing particularly well its continuity and intergradation with the organic basis of the columnar repair-substance. In the centre of a pearl it may contain, in addition to the

central cavity, secondary cavities in its substance, in which organic particles are lodged (fig. 20).

The variations of coarsely alveolar structure which amorphous substance shows (*e. g.* Pl. XL, fig. 29 *a* and Pl. XLII, figs. 40 & 41) recall those structures which Bütschli (6, Taf. iii. figg. 20-33) describes in the sphaerocrystals of (?) Trydinite formed when the siliceous concretionary substance of the Bamboo (known as Tabaxir or Tabasheer) is heated; this structure is probably in great measure the expression of the physical conditions (surface tension, etc.) which prevail when two substances in solution or in a colloidal state separate from one another to form a sphaerocrystalline mass.

Pl. XLII, figs. 37 & 39 are of interest as showing another variation of the nacre, in the direction of columnar substance. In this variety of nacre, the conchyolin-layers are connected by a number of thickened junctions, which tend to occur in groups and which are arranged in radial rows. In surface view these junctions appear as groups of dark spots on the conchyolin-layers; in radial section they are as shown in fig. 37, and can also be seen in Pl. XXXVI, fig. 13. These junctions seem to be thickenings of the walls which normally connect the several conchyolin-layers of the nacre to one another; they may, in fact, be regarded as local exaggerations of the condition described as "granular repair-nacre."

It is interesting to note the peculiar manner in which these repair-substances occur in Japanese "Culture Pearls." This name was given by the late Professor Mitsukuri (27 *c*, pp. 283-4, pl. xi. fig. 1) to pearl-like bodies—"blisters," as they would be called on the Australian fisheries—which are artificially produced in the Japanese Pearl-Oyster, *Margaritifera martensii** Dunker.

The production of these "Culture Pearls" is an extensive industry supporting about 100 persons, and is carried on by Mr. Mikimoto on leased areas of sea-bottom in the Bay of Agu, Shima Province, on lines originally suggested by Prof. Mitsukuri in 1890. It has been going as a commercial success since 1898, when the first crop of "Culture Pearls" was marketed. In 1905 the number of oysters operated on per year was from 250,000 to 300,000.

The process, which is protected by patents, is analogous to that adopted by the Chinese in the production of "Buddha Pearls" in the fresh-water mussel, *Dipsas plicatus*, and to the method discovered by Linnæus in the 18th century (see Herdman, 16 *a*), and consists in the introduction between the shell and the mantle † of a bead of nacre, which in due course (the time allowed in Japan is four years) becomes thickly coated over with nacre,

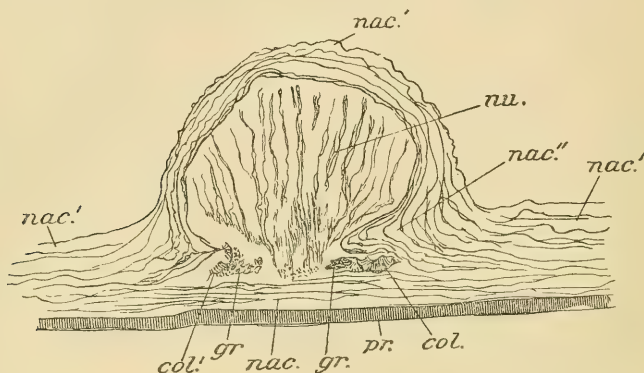
* This mollusc is regarded by some naturalists as a local race of *M. vulgaris*, to which it is undoubtedly very closely related. Whether it be called *M. martensii* or *M. vulgaris* var. *martensii* is largely a matter of individual taste.

† This is apparently done *via* the edge of the shell and not by drilling as in the Linnæus process.

forming a hemispherical, or sometimes rather more than hemispherical pearl-like excrescence, attached to the shell by its base. These "Culture Pearls" are produced in large numbers, and find a ready market for purposes for which "half-pearls" are used. They are now familiar objects in Europe*.

Text-figure 39 is a section of a Japanese "Culture Pearl," which I purchased in London, while still attached to the shell, and decalcified.

Text-fig. 39.



Section through a decalcified Japanese "Culture Pearl" still attached to the shell. *nu.*, the artificial "nucleus," a bead of nacre, the laminae of the nacre being cut transversely; *pr.*, prismatic layer; *nac.*, original nacreous lining, which existed before the nucleus was introduced; *nac.\"*, more recent nacre, lining the shell and extending over the "nucleus" to form the "Culture Pearl," secreted after the introduction of the nucleus; *nac.\"*, nacreous layers where the lining of the shell is carried over the nucleus; *col.*, repair-substance secreted in a zone around the point of contact between nucleus and shell, where the deposition of the shell-substance was not controlled by the mantle; *gr.*, granular matter, perhaps of foreign origin or of the nature of amorphous substance. $\times 10$.

The "nucleus" has been very skilfully introduced, so that there is practically no trace of "dirt" between it and the nacreous layer with which it is invested, as is so often the case in the "blisters" which have been produced by naturalists and experimenters from time to time. Moreover, the disturbance of the normal functions of the mantle has been so slight that, in the

* Needless to say, these bodies are not "Pearls," biologically speaking, but belong to the class of structures to which I have applied the name "blisters," familiar on the Australian Fisheries and in the Trade. Various naturalists have produced such bodies from time to time. I have recently seen some very beautiful ones produced in *Margaritifera maxima*, and I myself produced some presentable ones in *Margaritifera margaritifera* in Papua in 1899-1900. But although attempts have been made, and are still being made, to do this on a commercial scale, I am not aware that commercial success has yet been achieved anywhere else than in Japan; indeed, I think that the combination of circumstances which has led to the success of the Japanese enterprise—viz., skill, patience, and intelligence, backed by the best scientific advice and supported by cheap labour—has generally been lacking in other ventures. I may add that the price that could be obtained for the best of these gems is insignificant compared with the value of a real pearl of like size. No

particular sections that I examined, there was a marked absence even of the repair-substances. But, in the zone immediately around the point of contact between nucleus and shell, where, when the nucleus was introduced, the epithelium of the mantle was presumably unable to fit closely against the surfaces, it is otherwise. Here, on examining the whole "Pearl" as a transparent object after decalcification, an opaque ring or zone was distinctly visible. This was due to the presence of granular matter, perhaps derived from the exterior, perhaps from the tissues of the animal (text-figs. 39 & 40 B, *gr.*), and to very irregular columnar and amorphous repair-substance (*col.*, *col.'*). This columnar substance is shown in greater detail in text-fig. 40, A & B, corresponding respectively to *col.* and *col.'* in text-fig. 39.

In text-fig. 40, A, in the niche between the nucleus and the shell, where the mantle-epithelium could not reach, we see the product of its secretion consolidated away from the influence of the epithelium. Here the columns, instead of forming the characteristic palisade-like structure, with their long axes perpendicular to the secreting surface, are arranged in groups suggesting incomplete sphaerocrystals.

The curious fan-like arrangement which the columns take on in text-fig. 40, B, suggests that the repair-substance arose through an extravasation of the shell-forming fluids at the point *x*, the layer *nac.'* representing the first normal nacre, secreted by the mantle when it occupied that position, the irregular columnar and amorphous substance being due to the consolidation of the secretion which filled the space, triangular in section, which lay between the nucleus (*nu.*), the shell (*nac.*), and the mantle; the position occupied by the last named being represented by the layer of nacre marked *nac'*.

(13) VARIETIES OF CEYLON PEARLS.

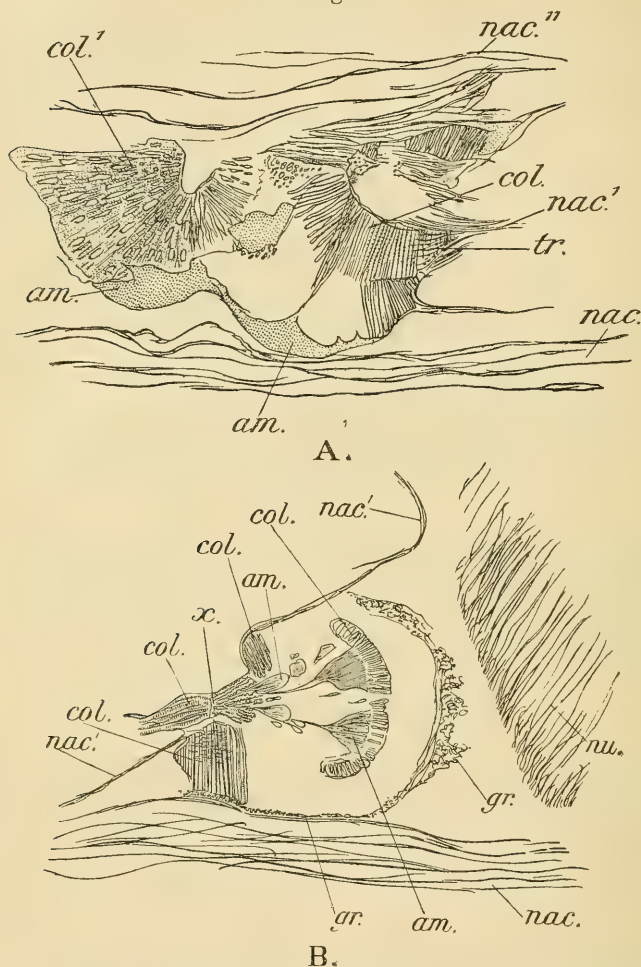
Pending a classification based on the nature of the causes which give rise to the formation of the pearl-sac, I propose, following Herdman, to separate the pearls which I have examined in or from the Ceylon Pearl-Oyster into two main groups, accordingly as they typically occur clustered in the neighbourhoods

really satisfactory proof has ever been given that free spherical "pearls" can be produced in this way, though Prof. Mitsukuri (*l.c.*) says that there are some hopes that this will be done. There is no theoretical reason why a modification of the Japanese or Linnæan operation should not be devised which would achieve this end—indeed, there is some reason to think that Linnæus actually did produce some round "pearls" and not only "blisters." But such bodies, if produced, would not be "pearls" in the strict biological sense, though it is quite likely that they would be marketed as such in quantities before the difference was detected.

Since writing the above, I have been informed by Mr. Toyozo Kobayashi, Professor at the Tokyo Higher Technological College, who is associated with Mr. Mikimoto in his enterprise, that perfectly free "pearls" have been produced by these methods within the last two years, but so far only exceptionally, and on a scale so small as not to be applicable commercially.

of the muscular insertions or singly in the non-muscular parts of the body-wall and mantle.

Text-fig. 40.



A. The irregular columnar and amorphous substances, shown at *col.* in text-figure 39. *nac.*, nacreous lining of the shell; *nac.'*, nacre deposited shortly after introduction of nucleus, passing over into the repair-substance (*tr.*); *nac.''*, nacre continuous with the layers investing the nucleus; *col.*, *col.'*, columnar repair-substance; *am.*, amorphous repair-substance. $\times 35$.

B. The fan-shaped mass of repair-substance, shown at *col.'* in text-figure 39. *nu.*, the introduced "nucleus"; *nac.*, the original nacreous lining of the shell; *nac.'*, the first layers of nacre, separated after the introduction of the nucleus; *col.*, columnar repair-substance; *am.*, amorphous repair-substance; *gr.*, granular matter, perhaps of extraneous origin. $\times 100$.

I adopt Professor Herdman's term "Muscle-Pearls" for the former class, while for the latter category I propose the name "Parenchyma-Pearls"*, because they occur typically in the parenchymatous subepidermal tissues of the non-muscular parts of the body-wall and mantle, or, by secondary displacement, in the more deeply seated soft tissues.

This group corresponds, I think, to Herdman's "Cyst-Pearls," but I prefer not to adopt the latter name, as, if the word "cyst" refers to the encysted Cestode, which Herdman associated with pearl-production, I have been unable to trace the connection between it and the pearl; while if it refers to the pearl-sac or "cyst," this is found around all pearls, including muscle-pearls. There is some reason for believing that some parenchyma-pearls arise from causes different from those that lead to the formation of muscle-pearls, and, indeed, it is quite possible that parenchyma-pearls have several modes of origin, as Herdman believes; but, on the other hand, their differences may be due in great measure to the different parts of the tissues in which they originate, and it is certainly quite impossible, in many cases, to say, from the structure of a pearl and of its nucleus and pseudo-nucleus, whether it is a "muscle-pearl" or a "parenchyma-pearl." With regard to Herdman's "Ampullar pearls," I cannot regard this group as of equal value to the above two classes, as, in my experience, so far as it goes, the "Ampulla" is of secondary origin, due to the absorption of the tissues intervening between the pearl and the shell, and to the epithelium of the pearl-sac and that of the outer face of the mantle thus becoming continuous.

Before going further I had better explain a term that I am introducing into this paper. I am restricting the word "Nucleus," as applied to the body found in the centre of a pearl, to those bodies which appear to be either of foreign origin or derived from the pearl-oyster otherwise than through the agency of the shell-secreting mechanism. To the bodies formed by the shell- and pearl-secreting mechanism, composed, as a rule, of different kinds of repair-substance (bodies which have no doubt often been wrongly mistaken for objects of foreign origin), I propose to apply the name "Pseudo-nucleus." I have endeavoured to be consistent in the use of these two terms, but, as is so often the case in biological matters, there is at times a difficulty in defining a sharp boundary-line between the objects to which they are respectively applied.

A. *Muscle-Pearls.*

I have set out above (p. 267) Professor Herdman's views on the nature and origin of these. Briefly recapitulated, they are the following. From some unknown cause, minute calcareous

* Rubbel (34 a) applies the term "Mantelperlen" to these bodies, a term which I prefer to mine, though it is too late to alter the nomenclature in this paper.

depositions or calcospherules* arise in the tissues, close to the attachments of the muscles to the shell. Ectoderm-cells may "migrate to the source of irritation, and thus be responsible for the deposition of a pearl." No explanation of the origin of these calcospherules is given, but Mr. Southwell thinks it is "almost certain that they are depositions from the blood," and refers to them elsewhere as "of excretory origin" (42).

I have been led by my observations to take a quite different view of these "calcospherules"†, and as their origin is so closely related to that of Muscle-Pearls, I cannot do better than begin the present section of my paper with an account of their structure and origin.

According to my view, Prof. Herdman's "calcospherules" are not free concretions at all, but are minute pearls, composed of hypostracum; and I propose, therefore, to call them "hypostracum muscle-pearls," to separate them from "nacreous muscle-pearls." As stated by Herdman, these bodies occur close under the epidermis (unless secondarily displaced, *e. g.* by the addition of new ones), and I usually find them in the region where the muscle-attachment epithelium passes over into the ordinary shell-secreting epidermis of the mantle. A group of these hypostracum-pearls is shown on Pl. XXXIX. fig. 22, which represents a portion of the mantle-musculature of one of the unlabelled specimens in the British Museum, examined entire in oil of cloves. The same pearls, decalcified, are seen in fig. 23. These little bodies measured from 0.02 to 0.5 mm. in diameter. In Pl. XXXVIII. fig. 19 similar bodies, *hyp.*, are seen in a section along with ordinary nacreous muscle-pearls; while single individuals are shown in Pl. XXXIX. figs. 21 & 21 *a* and Pl. XL. fig. 25. Sections ground from these bodies, or cut from the organic residues left when they are decalcified, show them to be composed of the same substance as the hypostracum of the shell. They consist of calcium carbonate, in fine fibrocrystalline form, showing radial and also concentric markings, with a small central cavity (Pl. XXXIX. fig. 21 *a*). Decalcified they also resemble hypostracum in all details of structure and reaction to stains (fig. 21). Their organic basis stains more blue with hæmatoxylin than the organic parts of the other shell-substances, and takes up carmine more deeply. Their alveolar structure is also much finer than that usually found in the columnar varieties of repair-substance, so fine, in fact, that in surface-sections the reticular structure seems almost like that of the protoplasm itself. As has been observed in the hypostracum of the shell, this substance sometimes passes over into nacreous conchyolin laterally. The

* This word is presumably intended to convey the same idea as the word "concretion" adopted by me (25) in 1902, *i. e.* a sphaerocrystal-like body arising in the tissues otherwise than by epidermal secretion; and therefore analogous to cholesterolin calculi, etc. (*cf.* Harting's "Calcosphærites," 12).

† I find that Rubbel (34 *a*), working on the freshwater Pearl-Mussel, *Margaritana*, has arrived independently at the same view of the nature of these bodies as that here propounded.

central cavity of a hypostracum-pearl may contain granules of doubtful origin, as in the case shown in fig. 21, but it is frequently quite empty. At times the organic basis of one of these hypostracum-pearls, when decalcified, shows a tendency to break up into segments, especially at its inner surface; the segments in such cases probably correspond to the outlines of the original secreting-cells; indeed, in such cases the whole body may have an almost cellular appearance, which is not surprising in view of the generally accepted theory that the hypostracum arises by direct transformation of the muscle-attachment epidermis.

These hypostracum-pearls shrink, on decalcification, to about one-third of their original diameters (Pl. XXXIX. figs. 22 & 23). When the tissue is old and defectively preserved, as in this preparation and in that shown in fig. 19, they come away from the wall of the enclosing sac during decalcification; but in better-preserved material, where the connection between the muscle-attachment epithelium and the pearl is maintained, the organic basis of the decalcified hypostracum-pearl remains attached to the wall of the sac (Pl. XXXV. fig. 8). Nacreous pearls, on the other hand, almost always shrink away from the sac on decalcification.

The smallest of these hypostracum-pearls that I observed measured about 0.02 mm. in diameter.

As the muscle-attachment epithelium, in *Margaritifera* at any rate, takes at most a very small part in shell-thickening, the size of these hypostracum-pearls is limited by the maximum thickness to which hypostracum normally attains. For further growth to occur, resulting in the formation of a nacreous muscle-pearl, it is necessary for some of the nacre-secreting epidermis to be present also (Pl. XXXV. figs. 8, s., & 9; Pl. XXXVI. fig. 10, sac.). Fig. 8, from a specimen given to me by Prof. Herdman, shows above a nacreous muscle-pearl and below a hypostracum muscle-pearl. Here we have a cyst, which is more or less spherical, and contains a large central cavity lined with a substance which is indistinguishable from the organic basis of hypostracum. Where an epithelium can be detected in the wall of the cyst (*m.ep.*) it possesses all the characters of muscle-attachment epithelium, its cells being continuous with the muscle-fibres, *m.*, on the one hand, and with the hypostracum, *hy.*, on the other. In some cases the muscle-attachment epithelium can be traced on all sides of the sac; in others, as in fig. 8 and fig. 10, c., only at certain parts. In still others no such epidermis is recognisable. I think, however, it is safe to assume, whether the hypostracum-pearl is surrounded by a sac of attachment-epidermis or not, that such a pearl can only arise where such a sac is present; and it is easy to detect the epithelium in most of the better-preserved examples (figs. 8, 9, & 10, *m.ep.*). Still, in some of the fairly well-preserved preparations I can identify no such epithelium. This is the case in Pl. XXXVI. fig. 11. In this example, which is on one of Prof. Herdman's slides, the hypostracum-pearl, which measures

80 μ in diameter, and has a wall about 10 μ thick, lies close to a nacreous muscle-pearl, about 1 mm. in diameter, the sac of which is shown at *ep.p.s.* The cyst is embedded in a strand of muscle traversing the mantle-parenchyma obliquely, and ending in muscle-attachment epidermis which was attached to the shell. (Such connections between the general musculature of the mantle and the shell occur here and there quite apart from the more regular muscle-scars. For examples of this in *Mytilus* see List, 27 b, Pl. 8. fig. 1.) The cyst contains at one point a little granular mass. The muscle-fibres here appear to be in direct contact with the hypostracum. The easiest explanation of this condition would seem to be the hypothesis that the original epithelium has disappeared. It is not difficult to suppose that a highly specialised "tendinous" epithelium, like the attachment-epidermis, whose fate seems to be to become a part of the shell, is incapable of regenerating itself, and, therefore, destined to die and disappear on ceasing to be functional. If we take this view, the typical hypostracum-pearl is not so much a stage in the development of a nacreous pearl as a phase parallel with it; the latter arising when the original sac contains some of the ordinary nacre-secreting epidermis, or cells capable of giving rise thereto, the former when it is composed of attachment-epithelium alone. The hypostracum-pearl would thus have a limited growth, the nacreous pearl an unlimited growth. However, in considering these cases where there does not appear to be any attachment-epithelium, it must be remembered that this particular epithelium is often very difficult to see, so that some workers have even failed to detect its existence on the regular muscle-insertions. Much light can no doubt be thrown on these questions by a really thorough study of the behaviour of the cells at the places where the muscle-attachment epithelium goes over into the ordinary epidermis of the mantle, and of the histological phenomena associated with the wandering of the muscle-attachment. The material of the pearl-oyster that I have examined so far is not sufficiently well preserved to allow of such study. So far as I know, this important matter has never been properly investigated in any mollusc.

I will now pass from the hypostracum muscle-pearls to the nacreous muscle-pearls. Typical instances of these are shown in Pl. XXXV. figs. 8 & 9 and Pl. XXXVI. fig. 10. These three examples are all explicable as derivatives of the hypostracum-pearl. Figs. 8 & 10 obviously lie in the borderland between one of the regular muscles and the parenchyma (fig. 8 is at the insertion of one of the pedal levators). Fig. 9, from one of Prof. Herdman's slides, is in a place in the free mantle where a few small muscle-strands (*musc.*) are attached to the shell. The sac of each of these pearls is lined in part by ordinary nacre-secreting epithelium, underlying which is the typical granular parenchyma, in part by muscle-attachment epithelium, continuous with the musculature. As the former is much more active than the latter, these pearls are all eccentric in shape, having a hilum

of hypostracum at one side, which, unlike the naacre, does not increase appreciably in thickness. The centre of each is a cavity, which in figs. 8 & 10 is obviously lined with hypostracum, and this hypostracum is connected by a plug of the same substance with the remaining muscle-attachment epithelium. In fig. 9 the growth of the naacre has pulled down the plug of muscle-attachment epithelium into the hilum, and produced quite a long strand of hypostracum-like substance. The presence of these hila, together with the effect of the mutual pressure of muscle-pearls when crowded together, has much to do with the generally irregular shape of commercial seed-pearls. Fig. 10, also from one of Prof. Herdman's slides, shows a very early stage in such a muscle-pearl, with a small cyst-like hypostracum-pearl alongside it. Here the ordinary epithelium of the sac seems to be gaining on the muscle-attachment epithelium.

These muscle-pearls always contain a central cavity, which may be broken up by trabeculae of hypostracum-like substance or of conchyolin, this substance being continuous with that forming the lining of the cavity. The cavity, like that of the pure hypostracum-pearl, may be empty or may contain more or less granular matter.

Muscle-pearls are often clustered and may be very numerous. Thus the old unlabelled material in the British Museum has dense clusters of these pearls in some places, and so has some of Dr. Kelaart's material.

It is by no means the case that muscle-attachment epithelium always persists in the sac of a muscle-pearl. The whole sac may pass over at an early stage into naacre-secreting epithelium, a process which is, perhaps, analogous to what occurs in the wake of an advancing muscle in the growing shell. This was apparently the case with the pearl that occupied the sac adjoining the body shown on Pl. XXXVI. fig. 11. The nucleus of this pearl is shown at fig. 12 on the same plate. The central portion of this pearl is composed of irregular conchyolin-like substance, which cannot be identified as hypostracum, and which quickly gives place to ordinary nacreous substance (*n.*). In the neighbourhood of this pearl is another, not figured here, the centre of which was comparable to the pearl shown on Pl. XXXV. fig. 8; this pearl had become more spherical secondarily by the disappearance, in the course of its growth, of the muscle-attachment epithelium. It is hard to conceive that these two pearls, and the hypostracum-pearl associated with them, are not all of similar origin.

Pl. XXXVI. fig. 13 shows the centre of another pearl, perhaps a muscle-pearl, from the mantle-margin, in one of Prof. Herdman's slides. This pearl appears to have measured about 2 mm. in diameter. The central cavity is about 0.1 mm. in its greatest diameter and is lined by abnormally thick conchyolin-like substance. Outside this are layers of ordinary naacre, which pass over into a form of repair-naacre showing radial markings,

probably due to variations in the rate of secretion of the constituent substances. This zone is 0.03 mm. thick. The central cavity is empty, except for a few granules.

In this case the muscle-pearl, if such it is, does not contain a pseudo-nucleus composed of hypostracum or a sphaerocrystal-like body such as those shown in figs. 19 & 20; and the real "nucleus" of such a pearl might be said to be a *cavity* which may or may not contain a few indistinct granules, perhaps of foreign origin.

The same condition is also typical of those pearls which I have examined from Dr. Kelaart's material. I have decalcified 38 of these in all (Pl. XXXVII. figs. 14, 15, & 16; Pl. XXXVIII. figs. 17 & 18; Pl. XLIV. figs. 46, 46 *a*, 47, 47 *a*, & 48). That these pearls are of the same nature as the other muscle-pearls seems probable from the fact that a few hypostracum-pearls occur mixed with the other pearls in Dr. Kelaart's specimens, and from the complete series of intergradations between the various forms described above, which is shown by the unlabelled specimens in the British Museum, described below. Pl. XXXVII. fig. 14 is a section of Dr. Kelaart's specimen showing "pearls in ovary." Each of these pearls lies in a cavity which doubtless was originally lined with an epidermal epithelium, though this can no longer be recognised owing to the state of preservation. The cavity is surrounded in every case by a layer of the granular subepidermal parenchyma (*par.*). Some of the pearls have been forced out of the subepidermal layer, and now lie embedded in the deeper connective-tissue, in which are seen muscle-bundles and tubules of the ovary.

In each case the centre of the pearl is a small cavity, containing a few granules or strands of what appears to be conchyolin; but the pearl in the lower right-hand corner contains also some columnar substance. The irregular conchyolin-like matter is well seen in the centre of the pearl in the top left-hand corner of the sketch, which is shown enlarged in fig. 15. It is interesting to note that the series of sections from which these drawings were made contained an example of the smaller Cestode larva, *Tylocephalum minus*.

Plate XLIV. figs. 46, 46 *a*, & 47, 47 *a* show two pearls picked from one of Dr. Kelaart's specimens, decalcified, and examined whole in oil of cloves (46 & 47) and after being sectioned (46 *a* & 47 *a*). Fig. 46 shows a dense central mass, of closely laminated nacreous substance, which on superficial examination might be taken for the remains of a dead parasite, but a section shows that the whole pearl is composed of nacreous substance around a small central cavity.

Fig. 47, examined whole, was extremely suggestive of a dead parasite; indeed, the concentric lamination of the pseudo-nucleus was not disclosed till sections were cut. These (fig. 47 *a*), however, furnished the explanation. The real centre of the pearl was, as in the rest of Dr. Kelaart's material, a nacreous

pearly mass, with a central cavity, showing at one side a plug of conchyolin-like substance. External to the normal central nacre were some irregular layers, such as one gets on the inner surface of the shell when a dark blotch or blister is caused by derangement of the secreting epithelium (compare the "Ölflecken" in *Margaritana*, Rubbel, 34 a). The opaque character of these layers, some of which were brown through the immigration or infiltration of what appeared to be cellular matter, others distinctly columnar (repair-substance), rendered the real nature of the pseudo-nucleus obscure till sections were cut. Outside these abnormal and pathological layers typical nacre was subsequently produced, thus giving a normal pearl with a dark centre.

The same characters are shown on Pl. XLIV. fig. 48, where the centre of the pearl appears opaque and granular for a similar reason. In this case the pseudo-nucleus measured about 5 mm. in diameter, and, examined entire, might have been taken for a dead parasite. It was such a nucleus, coupled with the presence of Trematodes, probably *Mutua margaritifera* Shipley & Hornell, in the tissues of Dr. Kelaart's pearl-oysters, that, in 1901, led me to the probably mistaken conclusion that a Trematode might be one of the organisms which afford the stimulus for the formation of the pearl-sac in *Margaritifera vulgaris*, as the Trematode *Gymnophallus* does in *Mytilus* * (25, p. 162).

But examination of sections (Pl. XXXVII. fig. 16 and Pl. XXXVIII. fig. 17) showed that the opaque pseudo-nucleus was due to a break in the continuity of the nacre; a layer of granular substance (*gr.*), apparently dead cells (perhaps of the nature of the "oil-spots" in *Margaritana*, or derived from an immigration of leucocytes such as Moynier de Villepoix observed (28, p. 112) or from Protozoan parasites), being followed by the secretion of two horny layers of amorphous repair-substance (*am.*, *am.'*), after which normal nacre resumed its development. The real centre of this pearl, as in the rest of Kelaart's material, consists (Pl. XXXVIII. fig. 18) of shreds of conchyolin-like material, and a few obscure granules, in a cavity which is surrounded first by granular repair-nacre and then by ordinary nacre.

In the two unlabelled specimens in the British Museum, from which Pls. XXXVIII.-XL. figs. 19-28 and Pl. XLIV. fig. 49 are drawn, while the pearls agree with those described above in their clustered habit, occurrence in the muscular regions, and association with hypostracum-pearls, we have more frequently as nuclei either hypostracum or special sphaerocrystal-like bodies, which I regard as formed of columnar repair-substance.

* Fuller knowledge and closer study lead me to doubt the accuracy of my own observations as to the occurrence of the remains of Trematodes in the pearls produced by the other species of molluscs referred to on p. 162 of my 1902 paper with the exception, of course, of *Mytilus edulis*, in which the relation between Trematodes and pearls is beyond question.

Pl. XXXVIII. fig. 19 shows a group of such pearls, scattered among which are hypostracum-pearls (*hy.p.*). The nucleus of the eccentric pearl at *nu.* is clearly composed, like that of the incipient pearl shown on Pl. XXXIX. fig. 22, *nac.*, of hypostracum, and resembles the hypostracum-pearl shown at fig. 21, which has a small quantity of granular contents. One of the columnar nuclei is shown enlarged at fig. 20. This is the nucleus of the large pearl shown in the upper part of fig. 19 (Pl. XXXVIII.). Centrally there is a small cavity, in which a granular mass of doubtful origin is noticeable (*gr.*). This cavity is surrounded by an irregular zone of substance which seems to be the same as the amorphous repair-substance of the shell (*cf.* Pl. XL. fig. 29). Externally to this there is columnar substance, forming a sort of sphaerocrystal-like mass, the fibro-crystalline calcium carbonate being deposited in a concholin-like basis, which, on decalcification of the pearl, remains as a framework. This substance is seen cut tangentially at one end of the pseudo-nucleus. Outside this is the normal nacre of the pearl. In one or two cases the amount of granular matter in the centre of the pearl was considerable; thus Pl. XL. fig. 24, which is taken from the same series as the preceding figures, shows the central portion of a pearl which has a dumbbell-shaped double nucleus, the larger half being about .17 mm. in diameter, and each half containing an opaque brownish mass of dead animal matter, perhaps of cellular origin, but quite unrecognisable. The contents of the two cavities were continuous at one point. There is nothing to suggest that either of these bodies represented a dead Cestode; I could find no denser portion, such as would naturally occur at the point representing the myzorhynchus, nor was there anything that could be safely identified as the cuticle of the parasite. If the contents suggested anything, it was rather the remains of a large Protozoan parasite, containing spore-like bodies in a plasma (like the Sporozoan spores which Dubois claims to have identified in the nucleus of a pearl from *M. vulgaris* from the Mediterranean, 7, p. 311, and 8, p. 104); or, perhaps, a mass of mucus containing a few cells. Each of these centres was surrounded immediately by the amorphous substance, this being followed by, and continuous with, a radially calcified layer, the bases of the calcareous prisms being evidently embedded in the amorphous substance, which extended up between them to form the organic framework of the columnar substance. This condition is comparable to that seen at *tr.* on Pl. XLI. fig. 30, which shows the amorphous substance secreted at the junction of two pearls in a compound pearl, passing over into columnar repair-substance.

Externally to the columnar layer of the pseudo-nucleus the normal nacreous layers of the pearl are formed.

The other extreme is shown on Pl. XL. fig. 25, a hypostracum-pearl .08 mm. in diameter, the central cavity of which has no contents whatever.

Pl. XL. fig. 26 shows a pearl having for its nucleus a double hypostracum-pearl, the two constituents being apparently separated by a mass of amorphous substance. Other examples were examined which showed intergradations between double and single hypostracum-pearls.

In fig. 27, from the same preparation as the above, there is a central cavity, containing a few granules, and surrounded by amorphous and columnar substances followed by nacre and finally by hypostracum. In another case in the same preparation the same state of affairs was shown, but there were further layers of nacre outside the hypostracum, resulting in a fair-sized pearl. These cases are of interest as indicating that the attachment of muscle-fibres to a pearl may arise secondarily, in the course of its growth. In some cases the columnar substance is stratified, as in the pearl at the bottom left-hand corner of fig. 19, Pl. XXXVIII. and in fig. 49, Pl. XLIV. In Pl. XL. fig. 28, which is the left-hand pseudo-nucleus of the double pearl shown in fig. 49, there is at one pole a distinct transition from the columnar matter of the pseudo-nucleus to normal nacre (*nac.*'), just as occurs in the substance of the pearls figured at Pl. XLI. fig. 34 and Pl. XLIII. fig. 43. This pseudo-nucleus is followed by normal nacre (*nac.*), after which there is a layer of brittle horny matter (*am.*), which I regard as analogous to amorphous repair-substance; this is followed by another columnar layer (*col.*'), imperfect on one side, and this again by nacre.

A preparation from the second unlabelled specimen in the British Museum showed, side by side, all kinds of intergradations between the various kinds of nuclei and pseudo-nuclei of muscle-pearls described above.

I regret that I am as yet unable to trace the origin of the muscle-pearls beyond the cyst-like sac, lined with hypostracum or another form of shell-substance. One or two preparations show cavities lined with a few cells, which may represent the first stages of pearl-sacs. Moreover, here and there, the relations of the epidermis, at the place where the muscle-attachment epithelium gives place to ordinary mantle-epithelium, suggest that these cysts arise by direct invagination at this region. What may be the mechanism which gives rise to this invagination I cannot say, there are certain indications that suggest that it may be associated with the presence of parasitic Protozoa, an idea suggested by me in 1902 (25, p. 162); but until I have been able to examine better-preserved material, it would be unwise to hazard yet another theory of pearl-production. At any rate, it is clear that, if pearls in *M. vulgaris* are of parasitic origin (and I adhere to the view that the distribution of pearl-producing examples of this and most other molluscs can at present best be explained on the parasitic hypothesis), the immediate cause of the pearl is not the *mechanical irritation* caused by the body of the parasite, but rather the *toxic properties of its secretions*, which lead to the pathological changes (formation of the tumours that

we call pearl-sacs) in the tissues; and that consequently the "cause" of the pearl is not to be looked for in the nucleus, which in the Ceylon pearl-oyster frequently does not exist, but rather in the tissues of the oyster. This is, after all, just what I said at the bottom of p. 142 in my 1902 paper.

The characters of muscle-pearls may be summed up as follows:—

(1) They usually and probably invariably arise in close association with the epidermis at the point where muscle-attachment epithelium passes over into normal nacre-secreting epithelium.

(2) They frequently occur several together or clustered in numbers.

(3) They are typically formed around central cavities in which granules may be, but are not necessarily, present, and which may be lined in the first instance with hypostracum, ordinary nacre, or repair-substances analogous to those which occur where the normal shell-secreting processes are disturbed.

(4) They are often associated with great numbers of little bodies, which Herdman calls "calcospherules," and which I regard as minute pearls composed of hypostracum.

(5) They are, according to Herdman, characteristic of certain of the Ceylon beds; and are, therefore, local in their occurrence, which would give support to a parasitic theory of their origin.

B. Parenchyma-Pearls ("Cyst-Pearls," Herdman).

This class contains a much more heterogeneous group of nuclei and pseudo-nuclei than the last. The pearls which it comprises may have arisen from more than one cause, and it is more than likely that a great many of the pearls which I refer to it are, in fact, of the same origin as muscle-pearls, but have been produced singly at spots where two or three muscle-fibres are attached to the shell, instead of in clusters at the regular muscle-insertions, and have consequently assumed a spherical form*.

Parenchyma-pearls often show a distinct central nucleus consisting of granules or masses of dark substance which might be either of parasitic origin or derived from dead tissue-cells (*e.g.* leucocytes). In some cases the nuclei of these pearls contain or consist of grains of sand or other foreign particles. The nucleus is typically succeeded by one or more layers of repair-substance, which often intergrades with the normal shell-substances (nacre etc.) of the pearl. In consequence of the presence of this abnormal shell-substance the centre of a parenchyma-pearl frequently contains a dark, spherical, concentrically laminated, radially striated pseudo-nucleus. This opaque pseudo-nucleus has no doubt on many occasions been mistaken for the remains of a parasite, in pearls decalcified and examined entire; but sections generally reveal its real nature unmistakably.

* These occasional attachments of small muscles to the shell on the general mantle-surface are well known. See *e.g.* List (27 *b*), pl. 8. fig. 1.

Cestodes may possibly occur in the centres of these pearls at times, as Professor Herdman maintains, just as grains of sand and other organic and inorganic particles certainly do; but this remains to be proved, and my material has afforded no evidence in favour of this much-quoted theory. And, even if it should be proved that Cestodes do occasionally occur as the "nuclei" of Ceylon pearls, the real causes which underlie the development of the pearl-sac (which is the essential factor in pearl-production) have still to be discovered. The characters of the centres of parenchyma-pearls can best be understood by reference to the next section of the paper, which is largely descriptive of them, though many of the pearls referred to therein are unquestionably "muscle-pearls."

(14) DESCRIPTIONS OF THE CENTRES OF INDIVIDUAL PEARLS.

In the absence of evidence connecting them with muscle-pearls I propose to treat the four pearls from the Persian Gulf, and the twenty-one pearls purchased for me in Ceylon by the Ceylon Company of Pearl Fishers, Ltd., as parenchyma-pearls, and to describe along with them eight of the pearls in Prof. Herdman's collection of slides which are not obviously muscle-pearls. These descriptions will be followed by an account of a number of samples and collections of pearls from *M. vulgaris* from Ceylon and other localities.

A. *Material from the Persian Gulf.*

It may be useful to begin with the material from the Persian Gulf. This, so far as it has been examined—for some of my specimens still remain unopened,—comprised three pearl-bearing examples, containing four small pearls. All these pearls appeared to be of the kind classified by Prof. Herdman as "cyst-pearls" and by the present writer as "parenchyma-pearls," as they seem to have arisen quite independently of, and away from, the muscle-insertions.

I append a short description of the conditions in each of these cases.

Preparation LXIV A contained a solitary pearl, about 2 mm. in diameter and slightly lenticular in shape, situate in the left mantle-lobe, on a level with the anterior end of the attachment of the outer gill-lamella. Unfortunately, owing to imperfect penetration in the embedding process, this pearl did not present a complete series in section. It lay wholly in the subepidermal parenchyma, which was sharply cut off from the underlying visceral connective-tissue by a layer of musculature, under which were the tubules of the ovary. The pseudo-nucleus was a radially calcified concentrically laminated body, about 3 mm. in diameter, with a few darkly staining granules in the centre.

The second specimen, Preparation LXIV B, contained another

solitary pearl, which before calcification measured somewhat over a millimetre in diameter, but when decalcified shrunk to .7 mm. It was situated in the left side, in the wall of the visceral mass, over the stomach. In section (Pl. XLI. fig. 33) the pearl is seen to lie in the subepidermal parenchyma (*par.*), projecting a little through the muscular coat (*musc.*) into the visceral connective-tissue (*ct.*), in which the tubules of the ovary (*ov.*) and muscular strands to the wall of the stomach (*musc.*) are seen. The pearl-sac has been ruptured, presumably by the evolution of bubbles of carbon dioxide during decalcification.

The pseudo-nucleus, which measures about .3 mm. in diameter, consists of several layers of columnar substance (*col.*) formed around a small central cavity. Probably such a pearl would, as it increased in size, grow through the muscular layer and work its way into the visceral mass; indeed, as soon as more than half its bulk lay on the inner side of the superficial musculature, the action of these muscles would tend to force it into a deeper position, where, relieved from the pressure of the shell, it would stand a better chance of growing into a perfectly spherical "fine pearl."

Preparation LXIV c, the third of these pearl-bearing examples from the Persian Gulf, contained two pearls, of minute size, about 2 mm. apart on the left side. Each was rather less than 1 mm. in diameter; one was round, the other elongated. Both lay in the subepidermal parenchyma, separated from the ovary by the usual muscular sheath of the visceral mass. Both had pseudo-nuclei of columnar substance. That of the more elongated one is shown in Pl. XLI. fig. 34. It has a central cavity, with irregular granular contents (*gr.*), surrounded by a number of layers of nacre (*nac.*), outside which is a complete layer of columnar substance (*col.*) which is coated on two sides by nacre, passing over at the two poles corresponding to the longest axis of the pearl into further coats of columnar substance (*col.*). The transition from nacre to columnar substance is very well seen.

The centre of the second pearl in this example was also composed of columnar substance, formed around a central granular mass. The granular mass measured about .02 mm. in diameter, the whole centre or pseudo-nucleus .3 mm. These preparations, apart from the difficulty of obtaining material from the Persian Gulf, are of interest as showing that the nuclei or pseudo-nuclei of the pearls produced by *M. vulgaris* in these waters do not differ from those of the pearls produced by the same species in Ceylon.

B. Pearls purchased in Ceylon.

I will now proceed to a short account of the nuclei and pseudo-nuclei of the twenty-one pearls purchased in Ceylon. All of these were decalcified, examined entire in oil of cloves, and drawn. Eighteen of them were also sectioned. (The drawings

of those not figured here are retained with the slides for reference.)

- (a) One (Preparation XLV) had no obvious nucleus or pseudo-nucleus.
- (b) One (Preparation XLIII) had a small sphaerocrystal-like centre of columnar substance, with no foreign contents (Pl. XLV. figs. 50 & 50 *a* and Pl. XLI. fig. 35).
- (c) Three (Preparations XL, XLIV, & LIV) had what appeared to be irregular masses of amorphous shell-substance, in central cavities, passing over into repair-substance (Pl. XLV. figs. 53 & 53 *a*; Pl. XLVI. fig. 57; and Pl. XLII. fig. 40).
- (d) Three (Preparations XLVII, LIII, & LIV c) had central cavities containing more or less granular matter, the character of which could not be determined, but which suggested dead organic particles (Pl. XLV. fig. 52 and Pl. XLII. fig. 36). This was surrounded by repair-substance of columnar structure.
- (e) One (Preparation LIV *x*) had in its central cavity granular matter in which diatoms, fragments of sponge-spicules, (?) minute sand-particles, and vegetable débris were present. These were surrounded by columnar repair-substance (Pl. XLIII. fig. 44).
- (f) One (Preparation LIV *e*) had, in the otherwise indistinguishable granular contents of the central cavity, a fragment of a Radiolarian shell (Pl. XLIII. fig. 45).
- (g) Four had undoubted sand-grains, forming the nuclei around which the pearl was laid down (Preparations LII, LIV A, LIV II, & LIV i). The largest diameters of the sand-grains in these four cases measured, respectively, .8 mm., .3 × .15 mm., .6 mm., and .3 mm. (Pl. XLV. figs. 54 & 54 *a*; Pl. XLVI. figs. 55 & 56).
- (h) One (Preparation LIV *k*) had a large sphaerocrystal-like pseudo-nucleus of repair-substance, intergrading with nacre, and a central cavity which had been partly obliterated in cutting the sections, but apparently contained several small quartz-fragments.
- (i) Six pearls (Preparations XLII, LI, LIV B, LIV D, LIV G, & LIV F) had, in their centres, bodies which were so hard that they broke away in sectioning, and were unfortunately not returned to me with the sections. The probable diameters of these bodies in the first five pearls were respectively .45 mm., .2 mm., .1 mm., .25 mm., and .6 mm. Preparation LIV F had a pseudo-nucleus of amorphous substance so dense that it broke away. In the cases of XLII, LIV B, and LIV G, I feel pretty sure that the nuclei here too were grains of sand, the others may have had either sand-grains or abnormally hard amorphous substance in their centres (Pl. XLV. fig. 51; Pl. XLII. figs. 37-39).

Turning now from the "nuclei" of these pearls to the "pseudo-nuclei" which surround them, these do not appear to present any characters which cannot be expressed in terms of the several pathological varieties of shell-substance described above. Thus Pl. XLIII. fig. 44 shows the nucleus (composed of diatoms, etc.) surrounded by typical amorphous and simply columnar repair-substance, followed by ordinary nacre. This appears to be equally the case in Pl. XLVI. fig. 55, where the nucleus is a sand-grain.

Pl. XLI. fig. 35 and Pl. XLV. figs. 50 & 50 *a*, which had no foreign nucleus, Pl. XLII. fig. 36, Pl. XLV. fig. 52 with granular contents in a central cavity, and Pl. XLII. figs. 37-39, in which example the nucleus was a sand-grain, and Pl. XLV. figs. 51 & 53 and Pl. XLVI. fig. 56, show these pseudo-nuclei to be composed of varieties of the columnar substance. Fig. 57 (Pl. XLVI.) and figs. 40-42 (Pls. XLII. & XLIII.) show it highly stratified, and presenting every gradation from amorphous to prismatic substance. This preparation is a "brown pearl," rather over 3 mm. in diameter, composed of the prismatic shell-substance, and probably produced in the mantle-margin. It consists of an outer zone, clearly identical in characters with the prismatic layer of the shell, and showing three distinct series of prisms. The bases of the innermost layer of prisms are shown in fig. 42, *pr.* Inside this normal prismatic substance is the "pseudo-nucleus," which consists externally of a layer resembling in every respect, except the diameters of its constituent elements, the prismatic layers (figs. 41, 42, *col.*). Internally this passes over, through a substance resembling irregular columnar repair-substance (fig. 41, *tr.*), into amorphous substance containing columns or scattered depositions of carbonate of lime (figs. 40, 41, *am.*). In places these bodies are ranged in radial rows, and the amorphous substance nearly reaches a stage which could be called columnar substance.

Just around the centre (fig. 40, *col.*) typical columnar substance occurs, passing over internally into amorphous substance. Owing to the impenetrability of the amorphous substance, the calcium carbonate has not been dissolved in the deeper layers of the pseudo-nucleus, and it is seen in the nucleus itself to occur in the form of perfect rhombohedra, a form I have never seen it take on in the alveoli of the normal or abnormal shell-substance. The resemblance of this pearl to the brown Scotch river-pearls (*e. g.* that figured by me in 'Nature' for Jan. 22nd, 1903, p. 281 [26]) is striking.

Preparation XLIII, from which figures 50 & 50 *a* on Pl. XLV. and fig. 35 on Pl. XLI. are drawn, showed an oval central body, about .6 mm. long, forming a "pseudo-nucleus." On superficial examination this nucleus is highly suggestive of a Trematode (fig. 50). But sections showed it to consist of a small sphaerocrystal-like body (fig. 35) about .08 mm. in diameter, surrounded by granular repair-nacre.

Figure 51 shows a pearl, the "pseudo-nucleus" of which is produced out in one direction as a strand of columnar and granular repair-substance extending through the pearl. This columnar substance is seen to pass over laterally into the ordinary nacre, and no doubt corresponds to an area in the pearl-sac at which the normal secretion-processes were disturbed. This was one of the examples in which the real nucleus broke away.

Fig. 36 on Pl. XLII., which is the centre of the pearl shown in fig. 52 (Pl. XLV.), enlarged, shows interesting transitional substance at one pole. This is further enlarged at fig. 43, Pl. XLIII. The pseudo-nucleus is seen to be discontinuous with the later-deposited shell-substance, a condition of things which is sometimes found, and which seems to suggest a pause before the epithelium becomes properly functional.

Plate XLV. figs. 53 & 53*a* show a pearl with a spherocrystal-like pseudo-nucleus, the longest diameter of which slightly exceeded 1 mm. In this case the columnar substance was very minutely reticulated and fell into three distinct zones. The pearl is interesting, as showing at one side a patch of columnar repair-substance apparently continuous with the nacreous layers, secreted over some foreign matter (granules) that had found their way into the pearl-sac during the course of the pearl's growth; this columnar substance formed a small "blister" in the substance of the pearl.

Where a sand-grain is present as nucleus, it appears to be followed, as a rule, by repair-substance; but in Pl. XLV. fig. 54 this is hardly discernible, except at one pole. This was a pearl which was drawn entire, and sent to be sectioned, when it was found that the nucleus broke away and resisted cutting. This nucleus was returned to me, and proved to be a siliceous sand-grain (fig. 54*a*), measuring about .8 mm. in diameter. It was surrounded by an opaque substance, probably "amorphous repair-substance."

Fig. 56 (Pl. XLVI.) shows a sand-grain which measured about .35 × .25 mm., surrounded first by amorphous substance, then by stratified columnar substance.

Fig. 55 (Pl. XLVI.), taken from a pearl which I have preserved entire, shows a pyriform sand-grain, .66 × .5 mm., surrounded by a thin layer of columnar substance, followed by nacre.

Figs. 37-39 (Pl. XLII.) are from the capsule surrounding a nucleus which broke away and was probably a sand-grain. Here, again, we have first the amorphous substance, passing over into "columnar" substance of spherocrystal-like form, with regular alveoli, which are approximately equal in length, breadth, and depth.

Figures illustrating minor varieties of the repair-substance as it occurs in the shell, in the pearl, and in the pearl pseudo-nucleus might be multiplied indefinitely, but I think enough have been given to illustrate my contention that these dark spherical bodies,

which so often suggest parasites, are usually in the Ceylon Pearl-Oyster pseudo-nuclei of sphærocrystal-like structure, each of which is reducible to a certain amount of amorphous non-calcified matter forming the lining of the nuclear cavity (figs. 35, 36, 37, 40, 41, & 44, *am.*), and the same substance, sometimes stratified, sometimes not stratified, containing depositions of calcium carbonate. It may be necessary to differentiate these pseudo-nuclei into two groups, typically represented by figs. 36 and 40-42 respectively—the one secreted in all probability before the epithelium of the sac could control its deposition at all (and thus comparable to a “Harting’s Body”); the other secreted by an already partly functional epithelium. When material with pearls in various stages of formation *in situ* in the tissues is available, this distinction may prove to have an important relation to the actual processes by which the pearl-sac arises, and to the difference between the nuclei of muscle-pearls and some parenchyma-pearls.

The most remarkable thing about this lot of pearls purchased in Ceylon is the high percentage which have as nuclei grains of sand or other foreign bodies. These cases might certainly be held to give support to the old theory that the stimulation of any intrusive particle, if it occurs at the right place, may give rise to a proliferation of epidermis resulting in the formation of a pearl-sac and a pearl. But, on the other hand, evidence is not lacking that the matter is by no means so simple as this. I am instituting some experiments on *Mytilus* (in connection with investigations on the life-history of the pearl-inducing Trematode that I am carrying on with the aid of a Government Grant) which will, I hope, throw some light on this question. It is idle to speculate, without experiments on living molluscs, whether these particles enter the tissue (*a*) in connection with mechanical injuries to the shell, as Herdman suggests, or (*b*) from the intestine, by perforation of the wall, and escape of such bodies as are seen in figs. 44 & 45 (Pl. XLIII.) into the blood, or (*c*) through lesions of parasitic origin.

With regard to the last-named figures, it is interesting to note that so long ago as 1857 Kelaart (27) suggested that the siliceous skeletons of diatoms might become the nuclei of pearls.

C. Professor Herdman’s Slides.

Professor Herdman’s preparations, illustrating pearls, which he very kindly lent me, consisted (omitting a few preparations of clustered hypostracum-pearls) of 24 slides, showing about 25 pearls in section. Of these pearls 13, representing 7 preparations, were obviously muscle-pearls, some of which are shown in figs. 9-12 (Pls. XXXV. & XXXVI.). In four of these preparations the cyst-like hypostracum-pearls were also present.

Eight pearls which were not obviously muscle-pearls, representing six preparations, are briefly described below.

(*a*) A pearl described in the label of slide as a “muscle-pearl.”

It was about 1.3 mm. in diameter, and situated in the body-parenchyma over the ovary (as in the Persian Gulf examples described above). The centre was a mass of concentrically laminated columnar substance, passing over externally into nacre and about 0.5 mm. in diameter. I treat it here provisionally as a parenchyma-pearl, as there is nothing to suggest that it is a muscle-pearl.

(b) This was a nice little spherical pearl, well out in the mantle. The centre was a sphaerocrystal-like body, of the same nature as those shown in figs. 35 & 36 (Pls. XLI. & XLII.). There were no recognisable foreign contents.

(c) This showed a pearl in the parenchyma over the ovary, as in the Persian Gulf specimens, with, apparently, all the characters of a "fine pearl." It had a large dark pseudo-nucleus, 0.4 mm. in diameter, much like that shown on Pl. XLVI. fig. 57. There was a central cavity, 0.025 mm. in diameter, containing a small granular mass; this was followed by nacre, then stratified columnar substance, then nacre again.

(d) Showed two pieces of free mantle, sectioned, one with one and one with two pearls *in situ*. In the case of the former the pseudo-nucleus was incomplete, but could be seen to be composed, in part at least, of columnar repair-substance. In the other specimen, both pearls had centres resembling those in Dr. Kelaart's material, and may well have been muscle-pearls.

(e) The central part of this pearl is shown on Pl. XXXVI. fig. 13. The pearl is quite close to the mantle-margin, in the musculature. In the centre there is a cavity with a few granular contents. This is surrounded by what appears to be ordinary nacre, then nacre with radial reinforcements, then nacre again. It suggests a muscle-pearl rather than a parenchyma-pearl.

(f) Contained a pearl, near the mantle-margin, the pseudo-nucleus of which was not complete. It consisted of alveolar-columnar matter; its centre could not be made out.

This preparation also contained an example of *Tylocephalum minus*.

The remainder of the pearls in Prof. Herdman's collection, four in number, appeared to be incomplete preparations, as no nuclei or pseudo-nuclei could be observed.

D. Unlabelled Pearls (dry) in the British Museum.

In September 1911 Mr. E. A. Smith, I.S.O., allowed me to examine four dry pearls, from a small collection of pearls and attached pearls and blisters, preserved in the Mollusca cabinets at the British Museum.

These specimens were unlabelled and without history, but their general characters (colour etc.) were those of *M. vulgaris*, and the fragments of shell to which some of them were attached were undoubtedly referable to this species, and probably to examples from Ceylon (heavily incrustated and much corroded with *Cliona*).

Three of these pearls were decalcified, and one of them, Preparation LXXXVI A, was also sectioned. All showed centres of the same class as those of the pearls in Dr. Kelaart's collection—that is to say, central cavities containing irregular conchyolin-like strands and a few granules. Two of these pearls were fair spherical pearls, about 3 mm. in diameter, which would have ranked as “fine” pearls or “cyst-pearls,” but for blemished surfaces. The third was a multiple pearl, secondarily attached to the shell, and showed, by the presence of distinct traces of hypostracum in its substance, that it had arisen in a muscular part.

E. *Collection of Pearls given to me by Mr. Max Mayer.*

In April 1911, Mr. Max Mayer, of Hatton Garden, London, and Paris, dealer in precious stones, most generously gave me for the purposes of my work a number of pearls, mostly of the baroque and seed class (though some could better be described as pearls that would have ranked as small “fine” pearls, but for defects of shape, colour, or surface). These included a sample which, after eliminating a number of pearls that, from their colour and other qualities, Mr. Mayer considered were derived respectively from Australia and Panama (these will be dealt with in another paper), left a mixed lot of 115 pearls, most of which showed more or less of the characteristic and indescribable creamy colour which is distinctive of the pearls of *Margaritifera vulgaris*. Mr. Mayer had no hesitation in saying that the majority of these were almost certainly Ceylon pearls, though he emphasized the fact that it is not often that pearls reach the European markets accompanied by “certificates of birth,” and that the sources of these specimens could only be judged from their respective characters.

These 115 pearls were decalcified and eight of them were sectioned, and several others were dissected to expose the nature of the “nucleus” or pseudo-nucleus.

Of this collection not one had a nucleus that could be identified as a Cestode, or indeed as any parasitic worm. Sixty of them had sphaerocrystal-like pseudo-nuclei composed of columnar repair-substance, sometimes simple, sometimes stratified, sometimes interstratified with other repair-substances. In some cases a few granules could be detected in the centre, in others nothing of the kind could be made out. These pseudo-nuclei were generally less transparent than the residue of the pearl, often almost opaque but in every case their nature was obvious. Forty-two pearls were of the kind described from Dr. Kelaart's specimens in the British Museum, *i.e.* they had either no obvious nuclei or their centres contained cavities in which were a few strands of conchyolin-like substance. Six others were of the same class, but contained some refractive granular matter. One double pearl showed a columnar pseudo-nucleus in one constituent and a centre of the “Kelaart” type in the other, while another,

a quadruple pearl, showed nuclei transitional between these two types.

There remain the eight examples which had to be sectioned to disclose the nature of their centres, owing to opaqueness. The first, Preparation XCIII, had a dark pseudo-nucleus which proved to be composed of stratified amorphous substance, in fact, a sort of horny pearl or periostracum-pearl. It was too hard to section properly, and its real nature was discovered only by dissection of the pseudo-nucleus. Preparation XCIV was a triple pearl, and contained pseudo-nuclei of three kinds, a "Kelaart" pseudo-nucleus, one composed of columnar substance, and one composed of concentrically stratified amorphous substance. Preparation XCV had an irregular dark nucleus which in section proved also to consist of stratified repair-substance, interstratified with granules. In Preparation XCVI the centre was a hard mass of columnar substance, containing a body that broke away and may have been either amorphous substance or a hard body of foreign origin. Preparation XCVII contained a typical columnar body, masked by a thick outer coat of amorphous substance. The remaining three had pseudo-nuclei of ordinary columnar substance.

I cannot say whether any of the above pearls contained minute quartz-grains or other foreign inorganic bodies, as this cannot be determined, even with the aid of polarised light, in a great many cases, until sections are cut, owing to the high degree of double refraction possessed by the conchyolin, and the distortion of its original arrangement in the decalcifying process. But such foreign bodies were detected in two pearls given to me at the same time by Mr. Mayer, which were, however, more probably from *Margaritifera margaritifera* var. *mazatlanica* (Panama Shell) than from *M. vulgaris*.

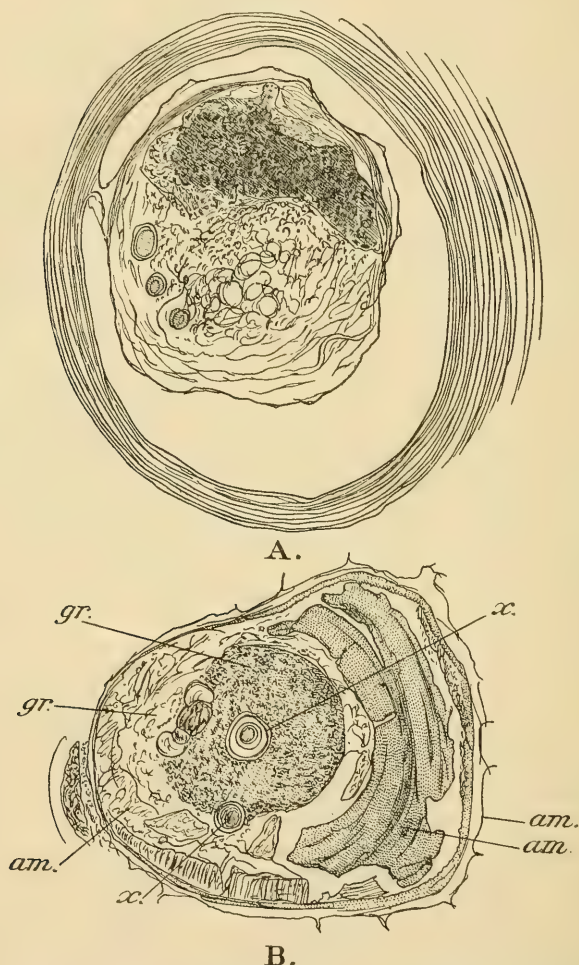
F. *Collection of Ceylon Pearls given to me by*
Mr. E. Hopkins.

In October last Mr. E. Hopkins, dealer in precious stones, of Hatton Garden, kindly gave me a parcel of fifteen small pearls, which he believed to be Ceylon Pearls. He wrote me (letter of 26th October, 1911): "The pearls were obtained from a dealer whose son visited the Ceylon Fisheries on the last occasion when they were open, and from what he has told me I have every reason to believe that these were part of the goods which he brought back." These fifteen pearls were decalcified and examined as transparent objects, and four of them, which could not be satisfactorily made out otherwise, were subsequently sectioned. Most of these pearls were of the "muscle-pearl" class, small and angular, but two or perhaps three, both from their more spherical shape and different nuclei or pseudo-nuclei, may more properly be treated as parenchyma-pearls.

Twelve of these pearls had centres of the kind characteristic of

the pearls in Dr. Kelaart's specimens, described above, *i.e.* had no obvious nuclei, but simply central cavities containing either a few irregular strands of conchyolin-like substance or obscure granules. Two out of these twelve were sectioned. One, Preparation

Text-fig. 41.



A. Centre of a Ceylon pearl given to me by Mr. E. Hopkins. Decalcified and examined whole in oil of cloves. Examined thus the body might be taken for the remains of a Platyhelminthian parasite.

B. The same in section. The body is seen to be a "pseudo-nucleus" consisting in great part of amorphous substance, *am.*, along with which is some granular matter, *gr.* In the centre are some strange spore-like bodies, *x.*, of doubtful origin (Preparation LXXXV L). $\times 400$.

LXXXV A, had its central cavity lined with hypostracum, as in the pearls described from the unlabelled specimens in the British Museum. The other had a central cavity lined on one side by a hilum-like plug of hypostracum, giving the pearl a reniform outline, and on the opposite side by columnar substance, going over into naere. Two of these muscle-pearls were composed of several fused units.

There remain three pearls which have some claims to be treated as parenchyma-pearls. One of these, which was not sectioned, had in its centre a string of brownish granular matter, .66 mm. long by .17 mm. wide, of doubtful origin (Preparation LXXXV o). Another (text-figure 41, A & B, Preparation LXXXV L) had a pseudo-nucleus .1 mm. in diameter, which, examined entire, might have been taken for the remains of a minute Platyhelminthian parasite, but which on section proved to be made up in great part of amorphous repair-substance. Finally, one pearl (Preparation LXXXV K), a round pearl just under 2 mm. in diameter, possessing apparently all the external qualities of a parenchyma-pearl, had for its centre a pseudo-nucleus of stratified columnar substance, 1 mm. in diameter, surrounding a sand-grain .35 mm. in diameter.

*G. Pearls from Margaritifera vulgaris from the
Gulf of Kutch.*

Being for the moment unable to obtain freshly preserved material from Ceylon or Madras, I endeavoured to obtain examples of the same species, preserved with pearls *in situ*, from Northern India, and through the courtesy of His Highness the Jam Saheb of Nawanagar, better known to most people in this country as Prince Ranjitsinhji, I was supplied in October last with a valuable collection of preserved oysters, containing pearls, from the Nawanagar fishery. I wish here to record my indebtedness to His Highness, and to Mr. Merwanji Pestonji, Dewan of Nawanagar, for their help. My thanks are also due to Dr. G. A. Grierson, C.I.E., Director of the Linguistic Survey of India, and to Mr. R. E. Enthoven, I.C.S., for putting me in communication with the Authorities of the State.

The detailed histological examination of this material will take some time, but I have decalcified and sectioned a number of pearls, free and *in situ*, for purposes of comparison with the material from other sources.

As the Nawanagar fishery is little known to biologists, the following information, supplied to me by the Dewan, may be of interest.

The fishery, which belongs to H.H. the Jam Saheb, is carried on on the southern shore of the Gulf of Kutch, during the South-West Monsoon season, from June onwards. The ground on which the pearl-oyster is found is "usually the sloping bank of a reef, facing east or south-east, consisting of shingly sand and small

rocks and stones, clear of all mud." Mr. Pestonji says that the bottom of the sea around the reefs is muddy, and that it is believed that the heavy rains and seas wash away the mud from the Oyster-beds, and so make it easier to see and collect the oysters. "At high tide there is usually about ten to twelve feet of water over the Oysters. The oyster-beds are never dry, even at low water, there always being an inch or two of water draining off" *.

The fishery is carried on by wading, at low tide. "During the Monsoon season four or five hundred men are sent out to a certain reef, where they tramp about and pick up the oysters as they come upon them. They stay three or four days on each reef, and when one reef has been searched they move on to another. Each man is rewarded according to the number and nature of the pearls found in the oysters he brings in."

The oysters are not "rotted," as in the case of the Ceylon pearl-fisheries, but are opened one by one, and the pearls removed "by scraping the flesh gently with a blade of a knife."

The number of oysters fished annually is about 150,000, on an average. The value is uncertain. The number of pearls extracted from these oysters comes to about 20,000 and over. They vary in size from seed-pearls to those weighing 20 grains and over. The lustre and colour are of first-class order, but the shape in over 60 per cent. of the pearls is poor.

Mr. Pestonji estimates that if care is taken to pick up oysters which are about four years old, about 10 to 15 per cent. of them contain pearls. He says, in a letter dated November 14th, 1911: "Lately we opened oysters three times. The first time we opened 643 oysters and got 452 pearls. The second time we opened 770 oysters, and got 537 pearls. The third time we opened 845 oysters, and got only 379 pearls." Mr. Pestonji includes the minute "dust" pearls as well as pearls of different sizes and shapes in this statement, and explains that there are often as many as fifteen or more minute pearls in a single oyster.

Eighteen pearls from this collection have so far been decalcified and examined, and thirteen of these have been sectioned. Some of these were sectioned *in situ* in the tissues, others were pearls which had fallen out of the tissues in the preserving process. They differed in no recognisable microscopic features from the pearls produced by the same species in Ceylon and the Persian Gulf. Thirteen of these pearls, six of which were from one specimen and three from another, were of the same character as those described from Dr. Kelaart's material in the British Museum, that is to say, they had a small central cavity, surrounded by ordinary nacre. The remainder had more or less obvious pseudo-nuclei, composed of columnar or alveolar substance, in some cases interstratified with nacre. Two of these (Preparations N. VIII. and N. IX.) had nacre inside the columnar substance, with

* Spring tides rise 18 ft., and neaps 14 ft., at Rojhi, an island near the town of Nawanzar, according to the Admiralty Sailing Directions, "West coast of Hindustan Pilot" (1898 edition).

a central cavity, and their difference from the "Kelaart" class of pearls was therefore probably due to a difference in their secondary growth, rather than in their primary origin. One of those sectioned (Preparation N. IV.) had a pseudo-nucleus composed of stratified columnar substance, with internally some nacre surrounding a small mass of brownish granules.

It cannot, I think, be argued in comparing these pearls with Ceylon pearls that they are all seed-pearls or "muscle-pearls." They occurred in all the usual parts of the external body-wall and mantle, and some of them had all the properties of small "fine pearls." Preparation N. VI., for example, was a beautiful little spherical pearl, of high quality, measuring about 2.5 mm. in diameter, which I was extremely reluctant to sacrifice in the interests of science, and a number of the others were solitary "parenchyma-pearls" of small size.

II. *Two Pearls from Margaritifera vulgaris from the Mediterranean, given to me by Professor Raphael Dubois.*

Professor Raphael Dubois most generously placed at my disposal for comparison two small pearls taken from *M. vulgaris* from the coast of Tunis. This species has firmly established itself in several parts of the Mediterranean, since the opening of the Suez Canal, having no doubt come through from the Red Sea, either in the free-swimming larval stage or as young spat attached to the bottoms of vessels. I can add nothing to what Dr. Dubois has already said about the structure of these pearls, (8) pp. 103-105. One contained a central body, rather less than .5 mm. in diameter, which on being sectioned proved to be composed of very homogeneous granular matter surrounded on one side by columnar substance and on the other side by "amorphous substance." The other contained a small yellowish spherical body, .08 mm. in diameter, which, examined in oil of cloves, showed no recognisable structure. In section it appeared to consist of a very small amount of granular matter, surrounded by what looked like stratified amorphous repair-substance. Dr. Dubois's observations have shown, without doubt, that the pearls produced by this species in the Mediterranean (and their single occurrence, in positions away from the muscle-insertions, renders it necessary to treat them in part at least as Parenchyma-pearls and not as Muscle-pearls) have not Cestodes in their centres, but have nuclei and pseudo-nuclei similar to those which I have described above, for pearls from the same species from other localities.

I. *Pearls from M. vulgaris from New Caledonia, given to me by Professor Seurat.*

Professor L. G. Seurat, at my request, very kindly sent me four small seed-pearls from *Margaritifera vulgaris*, from New Caledonia, and also a slide, showing a larger pearl from the same species

decalcified and mounted entire in Canada Balsam. In none of these could I find Cestode nuclei.

The example mounted as a slide was a pearl about 2 mm. in diameter, of oval shape, from the Isle of Pines. It had two pseudo-nuclei, side by side, both composed of columnar substance, concentrically laminated. One measured .5 mm., the other .3 mm. This pearl was subsequently sectioned, and no foreign matter could be detected in the nuclei. I decalcified and examined the other four pearls. The characters of three of them were nearest to those of the pearls in Dr. Kelaart's collection in the British Museum described above, but one had several centres, which were surrounded by columnar substance. The fourth had a little brown body about .2 mm. in diameter, which sections showed to be composed of unrecognisable granular matter surrounded by amorphous substance. No Cestode characters could be identified in it.

M. Seurat also sent me five slides, with sections of pearls from *M. vulgaris* from New Caledonia, which had been mounted in paraffin wax, but had not been stained or made into finished preparations. I stained and completed these, and found that they comprised about seven pearls, in all of which, so far as could be determined (for the series were not complete), the pseudo-nuclei were either simple cavities containing a few granules or strands of conchyolin-like matter, or masses of concentrically deposited, stratified columnar substance. There was no trace of anything that I could accept as a Cestode.

M. Seurat stated (37), p. 24, that these pearls had for nuclei Cestode larvæ, but I am unable to confirm this. In a recent letter he has informed me that this assertion was based on the appearance of the nucleus of a decalcified pearl, which was not, apparently, examined in section.

J. Pearl from M. vulgaris from Nossi-Bé, Madagascar.

M. Seurat also sent me an unmounted slide with sections of a pearl from this species from Nossi-Bé. The centre of this pearl was a mass of concentrically deposited columnar substance, 0.35 mm. in diameter, containing a cavity about 0.1 mm. in diameter.

K. Pearls from the Lapi Shell (M. vulgaris), from the Trobriand Islands, Papua.

Prof. W. R. Dunstan, F.R.S., Director of the Imperial Institute, very kindly allowed me to decalcify and examine two pearls from this locality, which were taken from among those on exhibit in the Papua Court at the Imperial Institute. These specimens had recently been sent home, by direction of the Administrator, the Hon. M. Staniforth Smith.

The pearl-banks occur on the western side of Kiriwina Island,

and the fishery is carried on by the natives from whom the pearls are bought by licensed traders. The annual yield is between £3000 and £4500 worth of pearls, as valued locally. The first of the two pearls examined was decalcified by me, but was not sectioned. The centre was a double pseudo-nucleus, slightly over a millimetre in length, and a little under a millimetre in breadth. It was obviously composed of stratified columnar substance. External to this the pearl, which was quite a good one, was composed of normal naere.

The second example was decalcified and examined entire, and then sectioned. The centre was a spherical pseudo-nucleus, rather less than half a millimetre in diameter, also composed of stratified columnar substance, with a minute central cavity, about 0.02 mm. in diameter.

These were certainly not "Muscle" pearls, but small "fine" pearls. The preparations have been returned to the Imperial Institute.

*L. Pearls from Placuna placenta, from Lake
Tampalakamam, Ceylon.*

In view of Mr. Hornell's statement, referred to in the account of the work in Ceylon, to the effect that he had determined that a Cestode larva, similar to or identical with that found in the pearl-oyster, caused the pearls produced in such quantities by *Placuna placenta*, the Window-pane Oyster, I thought that a study of this form would throw light on the problem in *M. vulgaris*. I made several fruitless efforts to obtain material from Ceylon and elsewhere. I examined one small pearl, decalcified and mounted whole, in Professor Herdman's collection (No. 78), labelled "Pearl Shelled from Mantle of *Placuna*." This pearl measures about half a millimetre in diameter, and the "nucleus" is a little yellowish body, about .05 mm. in diameter, and thus too small to be Hornell's larva (which is said to be from .2 to .4 mm. in diameter), even if it is of foreign origin. However, it was necessary to have material to section before the matter could be investigated. As I could not get other material Professor Dunstan very kindly allowed me to take a few *Placuna* pearls from the collection on exhibit in the Ceylon Court at the Imperial Institute. Two very well marked size-groups occur in the pearls in this collection, there being a majority of minute irregular pearls, 1 mm. in diameter and under, and a minority of larger ones, averaging from 2 to 3 mm. in diameter. Prof. Dunstan allowed me to take four of the latter and sixteen of the former. All these were decalcified, and two of the larger and four of the smaller were sectioned.

Of the larger pearls, Preparation CXLVI (sectioned) had for its centre a cavity, .05 mm. in diameter, containing a little irregular columnar repair-substance. Preparation CXLVII had a central cavity containing a small amount of yellow refractive

granular matter. The remaining two, which were decalcified but not sectioned, had no obvious nuclei, the centres being, apparently, like those of CXLVI and CXLVII. Of the sixteen minute pearls four were sectioned. Preparation CXXXV had in its centre a simple cavity, like the pearls in Dr. Kelaart's material of *M. vulgaris*. Preparation CXXXVI showed a central cavity, with around it some columnar substance, or perhaps hypostracum. Preparation CXXXVII had a large dark pseudo-nucleus, over half a millimetre long, which might easily have been taken for a foreign body, when examined entire, but which on being sectioned proved to be composed of concentrically laminated amorphous substance, passing over in places into columnar repair-substance, and containing a minute central cavity. Preparation CXXXVIII had in its centre a little brown body, probably composed of amorphous substance, but this specimen did not prove satisfactory on being sectioned. The twelve remaining pearls were decalcified and examined entire in oil of cloves, but were not sectioned. Of these four had either a small central cavity, surrounded by ordinary nacreous conchyolin, or no obvious nucleus or pseudo-nucleus. Six had such cavities, partly or entirely surrounded by repair substances or hypostracum, one had a few yellowish granules in its cavity, and one had a dark body, about .3 mm. in diameter, of doubtful nature, but showing no characters that would warrant its identification as a Cestode.

The absence of evidence in support of Mr. Hornell's Cestode theory of the origin of Placuna Pearls is an additional argument in favour of the opinion that the supposed observation of these worms by Mr. Hornell and Professor Herdman in the pearls of *M. vulgaris* was a mistake.

M. Pearls from Margaritifera margaritifera var. cumingii Reeve
(the Black-edged Mother-of-Pearl Oyster), from Rikitea,
Gambier Archipelago.

In order to enable me to compare the pearls of *M. vulgaris* with those of this species, in which Seurat claims that Cestodes occur as nuclei, M. Seurat most generously placed at my disposal some material. This consisted of three slides on which sections of pearls from this species had been mounted, but which had not been stained or completed. I stained and finished these three slides. In two of them the centre of the pearl could not be found, in the third there was not a section through the exact centre, but there was one that cannot have been far from it. This showed no Cestode remains, but a pseudo-nucleus rather less than half a millimetre in diameter, consisting in its more central part of concentrically deposited columnar repair-substance, passing over peripherally into alternate layers of amorphous and columnar substance, which in their turn passed over into nacre, through catenulated and granular transitional substance, such as I have described in *M. vulgaris*.

M. Seurat also gave me a piece of the latero-dorsal region of the body of this species, with pearls *in situ*. This I decalcified and examined in oil of cloves, and afterwards sent to be sectioned. At the time of correcting proof the sections had not been returned. Examined entire in oil of cloves this specimen showed a cluster of about ten pearls. Most of these were like those described from Dr. Kelaart's material of *M. vulgaris*, i. e., they had no obvious nuclei; one, however, had in its centre a minute hypostracum pearl or columnar pseudo-nucleus, about .1 mm. in diameter; one had a tiny refractive body, about .03 mm. in diameter, which may have been composed of amorphous substance; and one had some more opaque matter which, however, contained nothing that could be identified as a Cestode.

It would seem possible, in view of these observations, that M. Seurat may also have been led into the error of arguing that because the Trematode which is associated with pearls in *Mytilus* furnishes the stimulation necessary for pearl-production, therefore the Cestode in *Margaritifera* plays the same role. I hope shortly to receive further material from the French Pacific that will enable me to go into this question more fully.

I may add that my studies on pearls from *M. maxima*, and from the other varieties of *M. margaritifera* from other localities, so far as these studies have gone up to the present, afford no evidence of the occurrence of Cestodes in the centres of pearls.

(15) GENERAL SUMMARY.

The following are the principal conclusions to which these investigations have led me:—

(1) The evidence that the globular Cestode larvæ, which Prof. Herdman regards as the cause of the formation of "fine pearls" in the Ceylon Pearl-Oyster, are a young stage of the worm described by Shipley and Hornell as *Tetrarhynchus unionifactor* is quite inconclusive. I consider these worms to be more probably referable to the genus *Tylocephalum* (or an allied form), and have provisionally described them under the name of *Tylocephalum ludificans* and *T. minus*, spp. nn.

(2) The theory that these Tapeworms are the cause or a cause of the formation of pearls in the Ceylon Pearl-Oyster (in the sense in which the Trematode is the "cause" of pearls in *Mytilus*, where the pearl-sac is normally formed as a result of the specific stimulation of the worm) is supported by quite insufficient evidence, and even their occasional occurrence in the nuclei of Ceylon pearls has yet to be demonstrated*.

* Sir West Ridgeway, formerly Governor of Ceylon, Chairman of Directors of the Ceylon Company of Pearl Fishers, Ltd., in reply to a question put at the annual meeting of Shareholders in 1909 (reprinted in the 'Financial News' on December 21st, 1909), as to what was known with regard to the real cause and mechanism of pearl-formation, implied that the Directors were in possession of valuable information, of a secret nature, on the subject. "It was most undesirable at this moment that they [*i. e.* the Directors] should reveal the progress which had been made by

It appears, in fact, as though the simultaneous presence of pearls and Cestodes in the Ceylon Pearl-Oyster were a case of two parallel diseases, comparable to the case of a dog infected simultaneously with tapeworms and mange, or of a man suffering at the same time from echinococci and scabies. And even should it be found that tapeworms do sometimes form the nuclei of Ceylon pearls, an explanation of the reason why this occurs in some cases only is necessary. It is, of course, possible that in certain of the Ceylon banks conditions may exist which cause *Tylocephalum ludificans* to depart from its normal habit, and acquire an ectodermal instead of a fibrous cyst; or it might even be found that in certain banks another species of *Tylocephalum* (or other Cestode) occurs which, like the Trematode in *Mytilus*, normally and habitually gives rise to a pearl-sac in the tissues, and which has been confused with *Tylocephalum ludificans*. But, in any case, pearls formed around tapeworms, if such ever occur (and this still remains to be demonstrated), must be so comparatively scarce that, from the economic standpoint, the rôle of the tapeworm in pearl-production in *Margaritifera vulgaris* must be unimportant. Examination of such pearls from *Placuna placenta* and *Margaritifera margaritifera* var. *cumingii* as were obtainable failed to confirm the supposed occurrence of Cestodes as their nuclei.

(3) The shell of *Margaritifera* comprises in addition to the hinge-ligament the same layers as those of other typical Lamelli-branchs, viz. a periostracum (the outermost layer of which is secreted in a different manner to the remainder and is very much reduced in *Margaritifera*), prismatic substance, nacre, and hypostracum or muscle-attachment substance.

In addition to these, certain pathological varieties of shell-substance arise when the normal rhythm of secretion is disturbed, the chief of which are described as amorphous repair-substance (which is probably simply uncalcified conchyolin), columnar repair-substance, and granular repair-nacre. These substances intergrade with normal nacre and prismatic substance, and with each other. The peculiar characters of these substances are the chief cause of the distinctive appearance of the "pseudo-nuclei" of pearls. The shell-substance, except the hypostracum and the outer layer of the periostracum (and probably the ligament), is secreted in liquid form, and its structure and variation may be interpreted as the expression of the normal processes of the crystallisation of CaCO_3 in a colloidal medium, modified by the periodicity of the action of the shell-secreting tissues of the mantle.

(4) The "Calcospherules," which Herdman identifies as the nuclei of muscle-pearls, are not free concretions or "depositions

Mr. Southwell in his researches on this question; but he thought that gentleman would support him in saying that those researches had not been unsuccessful up to the present, and promised to be most interesting as well as satisfactory." Mr. Southwell's thoroughly frank statements of the case in his subsequent publications do not appear to me to reveal anything sufficiently epoch-making, from the commercial standpoint, to render such mystery necessary!

from the blood" (Southwell), but are minute pearls formed of the hypostracum or muscle-attachment substance. They are therefore not the *cause* of the nacreous muscle-pearls, but a phase parallel to them. There is some reason to believe that the origin of muscle-pearls is associated with pathological invaginations or immigrations of the epidermis at the points where the muscle-attachment epithelium passes over into the ordinary outer mantle-epithelium.

(5) Parenchyma-pearls (which name I apply to Prof. Herdman's cyst-pearls) may be formed around grains of sand or other foreign particles, organic granular matter of doubtful origin, or bodies composed of varieties of the shell-substance which arise when the normal rhythm of secretion is disturbed (repair-substance). A foreign nucleus is probably rather exceptional. The ultimate factors which give rise to the epidermal sacs in which they are formed have yet to be discovered. Many of them are probably of the same origin as muscle-pearls, except that they arise singly at points where a few muscle-fibres are inserted into the shell, instead of in clusters at the regular muscle-insertions. The dark pseudo-nuclei of these pearls, which may easily be mistaken for the remains of parasites, are usually composed of the repair-substances.

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(17) EXPLANATION OF THE PLATES.

(The magnifications quoted are only approximate.)

PLATE XXXIII.

- Fig. 1. Cestode larva (*Tylocephalum ludificans* or *T. minus*) in the act of migrating through the tissues of *Margaritifera vulgaris*. Drawn from one of Prof. Herdman's slides. The larva measured '12 mm. *pa.*, parenchymatous subepidermal tissue; *c.t.f.*, connective-tissue fibres.
- Fig. 2. Small larva, *Tylocephalum minus*, measuring '08 mm., in the muscular tissue of the mantle of *M. vulgaris*, without a surrounding connective-tissue cyst. From one of Prof. Herdman's slides. *mf.*, muscle-fibres in cross-section; *ep.*, epidermis.
- Fig. 3. Part of the fibrous cyst surrounding an example of the smaller parasite (*Tylocephalum minus*). In this case the parasite measured '08 mm. in diameter. *lt.*, liver-tubules; *il.*, inner, highly nucleated layer of the cyst. $\times 800$.
- Fig. 4. *Margaritifera vulgaris*. Epithelial cells from the muscle-attachment, showing the connection between the cells and the muscle-fibres. $\times 1000$.
- Fig. 4 a. *Margaritifera vulgaris*. Muscle-attachment epithelium, showing cells drawn out in fixation, and connective-tissue elements between their bases. $\times 1200$.

PLATE XXXIV.

- Fig. 5. *Mytilus edulis*. Section through the posterior adductor muscle-insertion and decalcified hypostracum. *mus.*, muscle-fibres; *hy.*, hypostracum, which remains adherent to the muscle-attachment epithelium, *ep.*; *hy.'*, segment of hypostracum, corresponding to single epidermal cell; *nac.*, nacreous layers of the shell, which have torn away from the hypostracum; *ct.*, connective-tissue fibres, joining the muscle-fibres to the attachment-epithelium. Preparation XXXIX. $\times 500$.
- Fig. 6. *Margaritifera vulgaris*, Persian Gulf. The part represented at A in text-figure 35, showing the point of origin of a new lip-lappet of the shell. *l.*, *l.'*, two successively formed lappets or marginal processes; *pr.*, *pr.'*, prisms of same; *s.pr.*, *s.pr.'*, conchyolin-septa of the prisms; *b.m.pr.*, conchyolin basal membrane of the prismatic substance of the first lappet; *per.*, periostracum of the second lappet, which appears to be nothing more than the outer conchyolin-membrane of the prismatic substance; *x*, point at which the second lappet arises from the first, the periostracum of the second lappet being continuous with the basal membrane of the first; *y*, irregular prismatic substance secreted at the junction of the two lappets. Preparation X. $\times 300$.
- Fig. 6 a. *Margaritifera vulgaris*, Persian Gulf. Decalcified shell showing junction between prismatic substance and nacre. *pr.*, prisms; *sep.*, conchyolin-septa between same; *sep.'*, the same in surface view; *anu.*, annular thickenings of the septa; *pr.b.*, basal conchyolin of the prismatic layer; *con.*, connecting layer of alveolar conchyolin between the prisms and the nacre; *nac.*, nacre. Preparation XI. $\times 400$.
- Fig. 7. *Margaritifera vulgaris*, Persian Gulf. "Lingah Shell" from London market. Section ground from an old heavy shell. Portion of the adductor-scar, showing the hypostracum, *hy.*, covered over in the direction of the umbo by nacre, *nac.'*; *nac.*, nacre underlying the muscle-scar, and secreted before the muscle-attachment had moved to this place; *hy.'*, *hy''*, extensions of the hypostracum interstratified with nacre. Preparation LXXV. $\times 120$.

PLATE XXXV.

- Fig. 8. Muscle-pearl and hypostracum "cyst," from the insertion of the posterior pedal levator muscle of *Margaritifera vulgaris*. From a Ceylon specimen given to me by Professor Herdman. The pearl is enclosed in a sac (which has been ruptured by gas-bubbles in the decalcifying process), consisting mainly of ordinary shell-secreting epithelium, but lined at one pole with muscle-attachment epithelium (*m.ep.'*). Opposite the ordinary epithelium

the pearl consists of typical coats of nacre; but at the point where the sac is lined with attachment-epithelium the pearl consists of hypostracum, which also (or a substance analogous to it) lines the central cavity. Beside the pearl, at *c.* is a cyst-like hypostracum-pearl, comparable to the lining of the adjoining nacreous pearl. This hypostracum-pearl consists of a cavity, lined with hypostracum-like substance (*hyp.*'), and on two sides it shows muscle-attachment epithelium, *m.ep.*'', but it has not acquired a lining of ordinary nacre-secreting epithelium, and hence no nacreous coats have arisen. *c.*, cyst-like cavity of hypostracum-pearl; *ep.*, shell-secreting epidermis; *ep.*', epidermis of pearl-sac; *m.ep.*, muscle-attachment epidermis; *m.ep.*', do. of pearl-sac; *m.ep.*'', do. of hypostracum-pearl; *m.*, muscle-fibres; *par.*, parenchyma; *hyp.*, hypostracum which lines the muscle pearl; *hyp.*', do. of the hypostracum-pearl. Preparation IV, 9. $\times 100$.

- Fig. 9. A muscle-pearl in the free mantle, from a slide in Prof. Herdman's collection. The area where the muscle-attachment epidermis is attached to the pearl is relatively very small. The greater part of the pearl-sac is composed of ordinary nacre-secreting epidermis, and consequently the pearl is composed of nacre at all parts but one. *o.ep.*, outer shell-secreting epidermis; *i.ep.*, inner ciliated epidermis of the mantle-cavity; *par.*, subepidermal parenchyma-cells, surrounding the pearl-sac; *m.ep.*, muscle-attachment epithelium, where hilum of pearl was attached; *musc.*, muscles of mantle; *sac.*, pearl-sac; *nac.*, nacre; *rep.nac.*, granular repair-nacre, around central part of pearl; *hyp.*, hypostracum. $\times 70$.

PLATE XXXVI.

- Fig. 10. An early stage of a muscle-pearl, from one of Prof. Herdman's slides. *sac.*, pearl-sac; *n.*, nacre; *par.*, parenchyma; *m.*, muscle-fibres; *hyp.*, hypostracum-like cyst, around which the pearl is formed; *m.ep.*, muscle-attachment epithelium; *c.*, a hypostracum-pearl. $\times 65$.
- Fig. 11. A cyst-like hypostracum-pearl in the muscle-bundle, without any apparent epithelial sac. From one of Professor Herdman's slides. The cyst adjoins the wall of a sac, *ep.p.s.*, in which a muscle-pearl was contained. *hy.*, hypostracum; *m.*, muscles; *par.*, parenchyma; *o.ep.*, outer shell-secreting epidermis; *ep.p.s.*, epidermis of pearl-sac. $\times 400$.
- Fig. 12. Centre of the decalcified muscle-pearl which occupied the sac adjoining the hypostracum-pearl shown in fig. 11. *c.*, central cavity; *gr.*, granules in central cavity; *n.*, nacre. $\times 500$.
- Fig. 13. Centre of a decalcified pearl, close to the mantle-margin, in one of Prof. Herdman's slides. *c.*, central cavity; *n.*, nacre; *rep.n.*, repair-nacre with radial reinforcements; *l.c.*, lining of the central cavity. $\times 300$.

PLATE XXXVII.

- Fig. 14. Four pearls "in ovary" of *Margaritifera vulgaris*, from Dr. Kelaart's material in the British Museum. The pearls are close together as shown, but their centres have been brought into the same plane in the drawing to show the "nuclei." Each pearl is surrounded by a mass of subepidermal parenchyma, *par.* *ep.*, outer epidermis; *ov.*, ovarian tubules; *m.*, muscle-bundles. Preparation XXVII, 8. $\times 30$.
- Fig. 15. The centre of the pearl shown in the top left-hand corner of fig. 14. *c.*, central cavities; *nu.*, nucleus-like matter, probably of the nature of conchyolin, contained in same; *rep.n.*, repair-nacre, with granular structure, following upon the cavity; *n.*, ordinary nacre of the pearl. Preparation XXVII, 8. $\times 400$.
- Fig. 16. The central portion of the pearl shown on Plate XLIV. fig. 48. *n.*, central nacre; *n.*', peripheral nacre; *c.*, central cavity; *gr.l.*, granular layer, causing the opaque yellowish appearance of the central mass. Preparation LXXI j. $\times 70$.

PLATE XXXVIII.

- Fig. 17. A portion of the granular layer of the pearl shown in fig. 16, more highly magnified. *n.*, central nacre; *n.*', peripheral nacre; *gr.*, granular layer, suggesting dead cells; *am.*, *am.*', two layers of amorphous horny substance. Preparation LXXI j. $\times 400$.

- Fig. 18. The centre of the same pearl, consisting of a cavity, about '08 mm. in diameter, surrounded by granular repair-nacre; the cavity contains a few irregular strands or laminae of conchyolin-like substance, together with certain granular bodies, possibly of cellular origin. Preparation LXXXI J. $\times 450$.
- Fig. 19. Group of muscle-pearls and hypostracum-pearls, from an old unlabelled example of *Margaritifera vulgaris* in the British Museum. The centres of the pearls have been brought into the same plane in the drawing. The pseudo-nuclei range from '08 mm. to '15 mm. in diameter. At the bottom and on the left-hand sides of the sketch are two pearls with eccentric pseudo-nuclei, in these cases composed of hypostracum, showing that the nacre-secreting epithelium arose on one side of the sac only. The preservation does not allow of any histological details of the tissues being shown. Four hypostracum-pearls are also shown. *nac.*, nacre; *nu.*, columnar pseudo-nucleus; *nu.'*, hypostracum pseudo-nucleus, only partly surrounded by nacre; *hy.p.*, hypostracum-pearls; *musc.*, muscle-bundles. Preparation XXVII, 4. $\times 30$.

PLATE XXXIX.

- Fig. 20. Centre of the pearl shown on the upper side of fig. 19. *nac.*, nacre; *col.*, columnar substance; *am.*, amorphous substance; *gr.*, granules in central cavity. Preparation XXVII, 4. $\times 350$.
- Fig. 21. A hypostracum-pearl, decalcified. *gr.*, granules in central cavity; *am.*, amorphous substance; *hy.*, organic residue of the hypostracum. Preparation XXVII, 1. $\times 550$.
- Fig. 21 a. Part of a section ground through the middle of a hypostracum-pearl, showing the columnar and stratified nature of its substance, and the small central cavity. From an unlabelled specimen in the British Museum. Preparation LXXVIII c. $\times 70$.
- Fig. 22. Portion of the mantle of *Margaritifera vulgaris*, near the margin, from a second unlabelled specimen in the British Museum. Cleared in oil of cloves, and examined entire before decalcification. The specimen shows a number of hypostracum-pearls *in situ*. At *nac.* is seen a large hypostracum-pearl in course of transformation into a nacreous pearl by the deposition of nacreous layers around it. Preparation XXIX. $\times 20$.
- Fig. 23. The same decalcified and examined in oil of cloves. *nac.*, as above. $\times 20$.

PLATE XL.

- Fig. 24. A double nucleus, with abundant contents, from a pearl in the same series of sections as figs. 19-21. *gr.*, granular substance, apparently derived from dead organic matter; *am.*, amorphous cuticle-like layers; *am.'*, a more deeply staining portion of the same substance, immediately surrounding the granular contents of the nucleus; *col.*, columnar substance; *nac.*, nacre. Preparation XXVII, 7. $\times 250$.
- Fig. 25. A small hypostracum-pearl. Central cavity without contents. Preparation XXVII, 11. $\times 100$.
- Fig. 26. A double hypostracum-pearl, forming the nucleus of a nacreous pearl. *am.*, (?) amorphous substance; *hy.*, hypostracum; *hy.'*, do. at periphery of amorphous substance; *nac.*, nacre; *nac.'*, columnar repair-substance. Preparation XXVII, 11. $\times 75$.
- Fig. 27. Small pearl, with nacreous substance overlain by hypostracum. *c.*, central cavity, containing a few granules; *am.*, amorphous substance which passes over into *col.*, columnar substance; *nac.*, nacre, which is succeeded by *hy.*, a layer of hypostracum, forming the outermost layer of the pearl. This specimen shows well the difference between the reaction to stain of hypostracum and the other substances, *e.g.* columnar substance. Preparation XXVII, 7. $\times 350$.
- Fig. 28. Pseudo-nucleus of the left-hand constituent of the double pearl shown in fig. 49 (Plate XLIV.). From one of the unlabelled specimens of *Margaritifera vulgaris* in the British Museum. *c.*, central mass composed of (?) amorphous substance and granules; *col.*, columnar substance; *col.'*, outer layers of the same, which pass over imperceptibly at one point into *nac.'*, nacreous substance; *nac.*, complete layers of nacre around nucleus; *am.*, horny layer, probably composed of amorphous substance;

col.''', incomplete columnar layer; *nac.*''', nacreous substance of the pearl. Preparation XLIII B. $\times 75$.

- Fig. 29. *Margaritifera vulgaris*, Persian Gulf. Portion of the repair-substance formed inside the shell to close a large hole made by a borer of some kind in the lateral region, below the umbo. *am.*, amorphous substance; *y*, outer surface of repair-membrane; *x*, *x'*, cracks in the outer face of the amorphous substance; *col.*, columnar repair-substance; *col.*', stratified do.; *tr.*, *tr.*', transitional substance (granular repair-nacre) from columnar repair-substance to nacre; *nac.*, nacre. Preparation LXXXVI. $\times 400$.
- Fig. 29 a. *Margaritifera vulgaris*, Persian Gulf. From a section through a blister on the shell-margin, formed over a *Leucodorye* tube. *am.*, amorphous repair-substance; *alb.*, the same with alveoli containing carbonate of lime; *pr.*, prismatic substance. Preparation XI. $\times 500$.

PLATE XLI.

- Fig. 30. *Margaritifera vulgaris*; Dr. Kelaart's material. Sections showing junction between two of the constituents of a "multiple pearl," with the various abnormal products which arose in association with the disturbances caused by the fusion of the two pearl-sacs, and the retreat of the wedge-shaped plug of tissue when its connection with its fellow of the opposite side was broken down by the absorption or degeneration of the membrane separating the two pearls. *p.*, *p.*', outer nacreous layers of the two pearls; *rep.nac.*, granular repair-nacre; *col.*, simple columnar substance, analogous to that found in the nuclei of some pearls; *am.*, amorphous substance showing rough stratifications, perhaps corresponding to pauses in the retreat of the wedge of tissue; *tr.*, transition from amorphous substance to columnar substance; *tr.*', transition from amorphous substance to granular substance; *nac.*', nacre of the compound pearl embracing both constituent pearls. Preparation LXXI c. $\times 300$.
- Fig. 31. *Margaritifera vulgaris*. Unlabelled specimen, British Museum. One end of the suture between the fused pearls shown in fig. 49, Plate XLIV. *nac.*, *nac.*', the nacreous layers of the two pearls; *col.*, *col.*', columnar substance, secreted after the epithelium had, through atrophy, lost its power of producing nacre; *ep.*, *ep.*', the degenerated remains of the epithelia of the pearl-sacs; *par.*, the remains of the intervening parenchyma. Preparation LXIII B. $\times 350$.
- Fig. 32. From the middle of the same suture; in this case the outlines of the parenchyma-cells, *par.*, are still visible. *ep.*, remains of the epithelia of the pearl-sacs. $\times 350$.
- Fig. 33. Parenchyma-pearl *in situ* in the tissues of *Margaritifera vulgaris*, from the Persian Gulf. *ep.*, outer shell-secreting epithelium; *ep.*', epithelium of pearl-sac; *par.*, subepidermal parenchyma; *gl.*, gland-cells in same; *musc.*, muscular coat of the visceral mass; *musc.*', musculature to wall of stomach; *C.T.*, connective-tissue of visceral mass; *ov.*, tubules of ovary; *col.*, columnar substance forming the centre of the pearl; *nac.*, nacreous portion of the pearl. Preparation LXIV B. $\times 80$.
- Fig. 34. Centre of a pearl from another example from the Persian Gulf. *gr.*, granular matter; *am.*, (?) amorphous substance; *nac.*, nacreous layer, immediately surrounding the "nucleus"; *nac.*', outer nacre; *col.*, columnar substance; *col.*', imperfect layer of same, passing over laterally into nacre. Preparation LXIV c. $\times 250$.
- Fig. 35. The central, spherocrystal-like pseudo-nucleus of the pearl shown in figs. 50 & 50 A (Plate XLV.); from the sample of pearls purchased in Ceylon. *gr.n.*, granular repair-nacre; *am.*, amorphous substance. Preparation XLIII. $\times 400$.

PLATE XLII.

- Fig. 36. The pseudo-nucleus of the pearl shown in fig. 52 (Plate XLV.); from series purchased in Ceylon. *gr.*, granular substance in central cavity forming the true nucleus; *am.*, amorphous substance; *nu.*, pseudo-nucleus, which here possesses a highly alveolar structure; *col.*, columnar repair-substance passing over laterally into *nac.*, nacre. Preparation LIII. $\times 70$.
- Fig. 37. Alveolar columnar repair-substance and radially reinforced nacre, from the pseudo-nucleus surrounding a sand-grain (or other hard body that broke away) in a pearl from the same series. *am.*, amorphous substance, forming

the innermost layer of the columnar pseudo-nucleus, *col.*; *nac.*, nacre; *nac.*', radially marked, catenulated variety of nacre, characterised by radial rows of junctions which occur in small groups between conchyolin-layers (*junc.*); *nac.*'', the normal nacre, passing over into this specialised variety of nacre. Preparation LIV α . $\times 300$.

Fig. 38. Tangential section through the alveolar-columnar substance shown at *col.* in fig. 37. $\times 300$.

Fig. 39. Tangential section through the radially catenulated repair-nacre, shown at *nac.*' in fig. 37. *junc.*, the groups of junctions in radial rows, seen in surface view. The section is near the inner surface of this layer. $\times 300$.

Fig. 40. Centre of the imperfectly decalcified brown pearl, shown in Pl. XLVI., fig. 57. *nu.*, nucleus with rhombohedra of calcite; *am.*', lining of amorphous substance; *col.*, columnar layer; *col.tr.*, transition-layer from alveolar-columnar substance to amorphous substance; *am.*, amorphous substance, with scattered alveoli, containing calcium carbonate. Preparation XL. $\times 250$.

Fig. 41. Part of the same pearl, external to that shown on fig. 40, showing the transition from amorphous substance, *am.*, with scattered alveoli, through an intermediate substance, *tr.*, to needle-like prismatic substance, *col.* $\times 250$.

Fig. 42. Transition from the needle-like prismatic substance, *col.*, shown in fig. 41, to the ordinary prismatic shell-substance, *pr.*, similar to that of the shell. *al.*, minute alveoli in the thickenings of the walls of the prisms, similar to those observed by Römer (32). $\times 250$.

PLATE XLIII.

Fig. 43. A portion of the repair-substance in the body of a pearl, shown at *col.* in fig. 36, showing transitions from amorphous substance to nacre. *nu.*, outer part of the pseudo-nucleus; *am.*, amorphous substance, with alveoli, which passes over into finely columnar substance, *col.* This in turn goes over through granular repair-nacre, *gr.*, into normal nacre, *nac.*', and is followed by layers of normal nacre (*nac.*) externally. Preparation LIII. $\times 400$.

Fig. 44. Portion of the contents of the central cavity of one of the pearls purchased in Ceylon; showing also a portion of the columnar substance which surrounded the centre. The contents drawn are selected from a number of the sections in the series cut from this specimen. *nac.*, nacreous substance of the pearl; *col.*, columnar repair-substance surrounding the nucleus; *am.*, *am.*', amorphous substance; *dia.*, diatoms; *spic.*, fragments of sponge-spicules; *veg.*, vegetable debris. Preparation LIV *j*. $\times 500$.

Fig. 45. Fragment of a Radiolarian shell, from the centre of another of the same lot of pearls. Preparation LIV *E*. $\times 600$.

PLATE XLIV.

Figs. 46, 46 *a*. Pearl from a cluster of pearls in one of Dr. Kelaart's specimens. Decalcified and examined, 46, entire in oil of cloves, 46 *a*, in section. The diameter of the pearl was just 2 mm., that of the central denser part was 1.3 mm. There is a simple central cavity. Preparation XVI. $\times 27$.

Figs. 47, 47 *a*. Another pearl from Dr. Kelaart's material, decalcified and examined, 47, entire, and, 47 *a*, in section. The diameter of the pearl was 2 mm.; that of the dark, opaque, yellowish centre rather over 1 mm. Examined entire the nucleus appears amorphous, and might well be mistaken for the dead remains of a parasite; but this peculiarity was found, on sections being made, to be due to a break in the continuity of the nacreous layers and the interpolation of a dark layer, composed of irregularly calcified conchyolin, and granules which are probably of extraneous origin. There is a small central cavity, as in the rest of Dr. Kelaart's pearls, with a plug of conchyolin-like substance at one side. *gr.*, granular dead matter; *col.*, columnar substance; *n*, nacre. Preparation XV. $\times 27$.

Fig. 48. A "double" pearl from Dr. Kelaart's material, decalcified, cleared, and examined entire. Sections through this pearl are shown on Plates XXXVII. & XXXVIII. figs. 16-18. The pearl was 2.25 mm. in diameter. The pseudo-nucleus was a dark opaque body, about 0.5 mm. in diameter, similar to that shown in fig. 47, and might easily be taken, on examination of the entire pearl, for the shrivelled remains of a dead parasite. Sections

showed that here again the real nucleus was a cavity containing strands or sheets of conchyolin-like substance and a few granular bodies, perhaps of cellular origin (Plate XXXVIII. fig. 18); while the dark appearance of the central mass was due to the interpolation between the proper nacreous layers of an abnormal pathological product. Preparation LXXI J. $\times 27$.

- Fig. 49. A double pearl from one of the unlabelled specimens in the British Museum; decalcified, cleared, and examined entire. The nucleus of the left-hand constituent is figured on Pl. XL. fig. 28, the characters of the substance at the suture between the two pearls at figs. 31 & 32 on Plate XLI. In the pseudo-nuclei of these pearls the columnar substance is stratified. Preparation LXIII B. $\times 27$.

PLATE XLV.

- Figs. 50, 50 a. The central portion of a white porcellanous spherical pearl, from the sample of pearls purchased for me in Ceylon by the Ceylon Company of Pearl Fishers, Ltd. Fig. 50, decalcified and examined whole in oil of cloves. Here the nucleus, when examined whole, might well be mistaken for a small Trematode. Fig. 50 a. Section through the centre of the same pearl. The pseudo-nucleus is seen to consist of an irregular nacreous body, shown in fig. 35 (Plate XLI.) to be granular repair-nacre, surrounding a minute sphaerocrystal-like mass; about 0.08 mm. in diameter. Preparation XLIII. $\times 27$.
- Fig. 51. Another pearl from the same collection. An oval pearl, of fine quality, 3.5 mm. \times 3 mm. in diameter. This pearl shows a tract of stratified columnar and granular repair-substance, extending outwards from the pseudo-nucleus and passing over laterally into the nacre. Preparation LI. $\times 20$.
- Fig. 52. Another pseudo-nucleus, from a pearl in the same collection. This was a small spherical pearl of fine quality, about 2 mm. in diameter. The columnar substance here, *col.*, is alveolar in structure, and surrounds a central cavity containing a few granules. For a section of the centre of this pearl, see fig. 36 (Pl. XLII.) Preparation LIII. $\times 27$.
- Figs. 53, 53 a. Centre of another pearl from the same series. The pearl was oval, about 3 mm. in diameter, with a faint zonal constriction and a rather coppery tint. Examined entire (fig. 50) it shows a large pseudo-nucleus, over a millimetre in diameter, which falls into three layers. It also shows a blemish in the nacre, coated over with repair-substance. Fig. 53 a shows the same in section. The columnar repair-substance is finely reticulated or alveolar. The blemish is caused by a few granules, which have found their way into the pearl-sac and have been covered over with columnar repair-substance, which passes over laterally into ordinary nacre. Preparation LIV. $\times 27$.
- Figs. 54, 54 a. Fig. 54. Central portion of another pearl, which measured about 3 mm. \times 2.75 mm. A pearl of fine colour, but with slightly irregular surface. The nucleus of this pearl is a sand-grain, enclosed in an opaque yellowish coat, probably consisting of repair-substance. At one pole is seen a process of repair-nacre, but, except for this, no columnar substance appears to surround the grain. Fig. 54 a. The sand-grain, dissected out from the above preparation. Preparation LII. $\times 27$.

PLATE XLVI.

- Fig. 55. Fine spherical pearl, from the same series, about 2 mm. in diameter. Nucleus a grain of sand surrounded by a thin layer of columnar substance, thickened at one pole. Preparation LIV H. $\times 27$.
- Fig. 56. Another pearl from the same series, a small spherical pearl about 2 mm. in diameter. The nucleus is a grain of sand, forming the centre of a typical pseudo-nucleus of columnar substance. Preparation LIV A. $\times 27$.
- Fig. 57. A brown pearl, spherical, 3 mm. in diameter, formed of the prismatic substance. From the same collection. *nu.*, pseudo-nucleus; *col.*, columnar substance; *am.*, amorphous substance; *col.*, fine columnar-prismatic substance; *pr.*, ordinary prismatic substance; *bl.*, blister formed over intrusive foreign matter. For the several substances of this pearl, more highly magnified, see Plate XLII. figs. 40-42. Preparation XL. $\times 27$.

- Fig. 58. *Tylocephalum ludificans*, sp. n. *Type*. Section through an example in the tissues of the Ceylon Pearl-Oyster in Professor Herdman's collection. Slide 94 of Professor Herdman's series. *a.*, armature of collar. This shows the myzorhynchus of "*Tylocephalum*" form, due to the posterior face (*m.p.*) being contracted and its surface thrown into folds and the anterior face (*m.a.*) stretched. Compare the adult *Tylocephala* in figs 61 & 62, and also the species shown in fig. 65. $\times 70$.
- Fig. 59. Section through another example of the same species, showing the "*Cephalobothrium*"-form of myzorhynchus; here the posterior surface of the myzorhynchus (*m.p.*) is tense, and its anterior surface (*m.a.*) is thrown into folds. *a.*, armature of collar. (Compare the adult worm in fig. 66.) $\times 70$.
- Fig. 60. An adult worm, which may be the adult of *Tylocephalum ludificans*, from the spiral intestine of *Aëtobatis narinari*. $\times 6$. From Dr. Shipley's collection.

PLATE XLVII.

- Fig. 61. The head of the worm shown in fig. 60, viewed as a transparent object. *m.*, myzorhynchus; *s, s', s''*, three of the four marginal suckers; *a.*, armature of collar; *seg.*, first proglottides. $\times 70$.
- Fig. 62. The same, in section; letters as above. $\times 70$.
- Fig. 63. Armature of collar of same, about point *a* in fig. 62. $\times 1000$.
- Fig. 64. Penultimate segment of same.
- Fig. 65. Head of *Tylocephalum uarnak* from *Trygon uarnak*. From a slide in Dr. Shipley's collection. *my.*, myzorhynchus, which here is fully protruded; *ma.*, anterior face of same; *mp.*, posterior face; *s, s', s'', s'''*, the four marginal suckers. $\times 45$.
- Fig. 66. Head of *Cephalobothrium aëtobatides* from *Aëtobatis narinari*. From a specimen in Dr. Shipley's collection. Letters as above. $\times 70$.

19. Mimicry amongst the Blattidæ; with a Revision of the Genus *Prosoplecta* Sauss., and the Description of a new Genus. By ROBERT SHELFORD, M.A., F.Z.S.

[Received October 7, 1911; Read February 20, 1912.]

(Plate XLVIII. * and Text-figures 42-46.)

Speaking in general terms the Blattidæ may be regarded as a somewhat defenceless group of insects, preyed upon by numerous enemies both vertebrate and invertebrate, to escape which they must rely on their skulking, cryptic habits, and on a high degree of speed when disturbed. In accordance with their cryptic mode of life most cockroaches are obscurely coloured, harmonising more or less perfectly with their inanimate surroundings, or, at any rate, displaying no conspicuous markings to attract the attention of potential foes.

Exceptions to this cryptically coloured type of cockroach, however, exist in some numbers and are dealt with in the following pages.

The Australian continent is the headquarters of a group of Blattidæ which presents all the features customarily associated with extreme unpalatability. This group is the *Polyzosteria* section of the sub-family Blattinæ. Nearly all the species are apterous and expose themselves freely, and many are endowed with a most repulsive odour. Mr. W. W. Froggatt informs me that *Polyzosteria limbata* Burn., *P. cuprea* Sauss., and others of this

* For explanation of the Plate see p. 376.



Horace Knight del. et lith

West, Newman chromo

MIMETIC COCKROACHES AND BEETLE MODELS.

genus and of *Platyzosteria* Br., are fond of sunning themselves on the tops of posts and tree-stumps. Commander J. J. Walker when collecting in Australia frequently encountered a species, *Cosmozosteria lateralis* Walk., which emitted so vile a smell that he always refrained from touching it. This species is russet-brown in colour with some variable yellow markings on the thoracic and abdominal tergites, and on each posterior angle of the ninth abdominal tergite is a brilliant orange-red spot; when the insect is at rest these two spots are almost concealed, the ninth tergite being somewhat retracted within the preceding one, but on the approach of an enemy the apex of the abdomen is elevated and slightly distended so that the orange spots become conspicuously displayed to view. A better example of a warning signal associated with highly distasteful properties could not be found.

Prof. Baldwin Spencer, writing in 'Nature' of July 28, 1892, p. 309, says:—"One morning, when Mr. Frank Connolly and myself were digging for worms, we accidentally cut in two a cockroach. From between the segments in its back it poured forth a milky-white fluid, possessing an odour so execrable and pungent that it drove us from the spot." It is unfortunate that the species was not identified, but I expect that it was one of the *Polyzosteria* group.

Commander J. J. Walker says of *Periplaneta fortipes* Walk., a synonym of *Platyzosteria nove-zealandia* Br., that it is "very evil-smelling," but that its smell "is quite mild in comparison with several of the Australian species." (Entom. Monthly Mag. (2) xv. p. 70 (1904).)

Dr. G. B. Longstaff recently took this species in some numbers in New Zealand, finding it, however, not in exposed situations, but under logs and the bark of dead trees. Quoting from his notebook Dr. Longstaff tells me that one specimen had a "moderate cockroach odour, evanescent," of another that it had "a strong peculiar fætor." The discrepancy may possibly be accounted for by sexual differences (see remarks later on *Eurycotis floridana* Walk.).

All the Australasian species of the *Polyzosteria* section appear to be conspicuous insects. Many of them are shining black, a colour which is noticeable enough in Nature when associated with free exposure; others are black edged with yellow, or with red legs. The species of *Anamesia* Tepp., are chestnut-brown banded or margined with yellow. *Cosmozosteria zonata* Walk., is black, banded with yellow or orange. Many of the species of *Polyzosteria* Burm. are bright with metallic colours, and *Euzosteria mitchelli* Angas, with its bronzy dorsal surface, spotted and banded with orange or yellow, its pale yellow ventral surface and sky-blue tibiæ, is the most gaudy cockroach yet discovered. In the New World the *Polyzosteria* section of the Blattinæ is represented by the genera *Eurycotis* Stål, and *Pelmatosilpha* Dohrn. The species do not appear to be so blatantly conspicuous as their Australian relatives, but it seems likely that most, if not

all of them, are endowed with very distasteful properties. Rehn and Hebard (Proc. Acad. Nat. Sci. Philadelphia, 1905, p. 32) write of *Eurycotis floridana* Walk. :—"When seized these insects emit a vile-smelling oily fluid. The females always produced far more of this than the males." This is a chestnut-brown species, but the larvæ have the thoracic tergites margined with pale yellow; it is found hiding under logs and stones. It is evident, then, that amongst the Blattidæ a nauseous odour or taste is not invariably associated with aposematic habits,—the insects themselves may be conspicuous enough when unearthed from their hiding-places, but the point is, that they do not voluntarily expose themselves, as do so many of the Australian *Polyzosteriæ*. Further confirmation of these rather puzzling facts is afforded by observations made by Mr. G. A. K. Marshall on two South-African cockroaches, *Deropeltis erythrocephala* Fab. and *Aptera fusca* Thunb. The first of these belongs to the subfamily Blattinæ and to a genus in which the males are winged and the females apterous. In both sexes the posterior margin of the fifth abdominal tergite is sinuate*, and beneath the tergite are situated glands from which a sticky fluid exudes when the insects are seized. Though it is reasonable to suppose that this fluid is a distasteful secretion of a defensive nature, it must again be noted that *D. erythrocephala* and probably most of the other species of the genus hide beneath stones and do not expose themselves voluntarily. Most of the species of *Deropeltis* are bulky insects, piceous in colour; in *D. erythrocephala* the head and legs are red. *D. dichroa* Gerst., from the Gold Coast, has a large fulvous macula on each side of the sixth and seventh abdominal tergites; whilst *D. paulinoi* Bol., from Angola, is equally conspicuously marked with rufous fasciæ on the lateral margins of the pronotum. The female of *Aptera fusca*, one of the Perisphæriinæ, is a large, robust insect, piceous with conspicuous transverse bands of ochreous or rufous; when seized it exudes a violet fluid which stains the fingers; this species also has cryptic habits. This is absolutely all the information that I have been able to gather about unpalatable species of Blattidæ, and it certainly is little enough. It is perhaps remarkable that the undoubtedly nauseous Australian species are not mimicked either by other orders of insects or by non-distasteful species of Blattidæ, but it must be remembered that the Orthoptera do not serve as models to other orders of insects—not a single instance has ever been recorded, and in Australia the paucity of cockroaches other than those of the distasteful group, is quite exceptional.

Although no Blattidæ are known to serve as models to mimicking insects, there are several which mimic insects other than Orthoptera, though in most instances the mimicry is of a very generalised nature. I have no reason to suppose that any of these mimetic Blattidæ are other than palatable.

* A generic character.

In a very superficial sort of way cockroaches and beetles may be said to be similarly constructed. In both the pronotum is large whilst the other thoracic tergites (in the winged species) are concealed; in both the membranous wings are covered by elytra or tegmina of a coriaceous or corneous texture. In fact only a slight modification of the cockroach-form is required to produce a distinctly Coleopterous appearance. The names *lycoides*, *buprestoides*, *coccinelloides*, *dytiscoides*, *silphoides*, given to species of Blattidæ by various authors, are sufficient evidence of their resemblance to beetles. It is quite an open question whether this generalised resemblance of certain Blattidæ to Coleoptera can be legitimately classified under the heading of Mimicry. It could well be argued that some of the species, at any rate, owe their beetle-like form to convergence in development, or, to use Sir Ray Lankester's term, that cockroaches and beetles are homoplastic forms. On the other hand, as will be seen later, some of the cases of resemblance are so detailed and close that it is impossible to regard them as anything but examples of true mimicry, and it becomes most difficult to draw the line between the two classes of resemblance. For convenience' sake, at any rate, throughout this paper the Blattidæ which resemble insects of other orders will be termed "mimics."

Examples of generalised mimics of the Coleoptera are furnished by species of *Pachnepteryx* Br., *Caloblatta* Sauss., *Paratropes* Serv., *Phoraspis* Serv., *Eustegasta* Gerst., *Achroblatta* Sauss., *Corydia* Serv., *Areolaria* Br., and *Hypnorna* Stål, whilst several species in other less specialised genera might be quoted. Of not one of these species can it be said that it is very like any definite species of beetle. *Eustegasta buprestoides* Walk., from West Africa, is a metallic green cockroach with round yellow spots on the tegmina, and as its name implies, it is very like a Buprestid beetle. But in spite of the most diligent search amongst collections of Buprestidæ, I have never found a species which by the greatest stretch of imagination could be regarded as even an indifferent model for the cockroach.

Belt speaks of mimetic cockroaches in 'The Naturalist in Nicaragua' as follows:—"The phosphorescent species of *Lamprolyridæ*, the fireflies, so numerous in Tropical America, are equally* distasteful, and are also much mimicked by other insects. I found different species of cockroaches so much like them in shape and colour that they could not be distinguished without examination. These cockroaches, instead of hiding in crevices and under logs like their brethren, rest during the day exposed on the surface of leaves, in the same manner as the fireflies they mimic"†. It was with much interest that I found in the Hope Museum, Oxford, a specimen of the cockroach *Achroblatta luteola* Blanch., with the following note in

* *I. e.* with the non-phosphorescent species, by which Belt appears to mean the beetles now known as *Lycidæ*.

† I quote from the Everyman's Library Edition (Dent & Sons, 1911), p. 243.

Westwood's handwriting attached to it:—"This *Blatta* lives on trees and closely resembles in its habits some of the large Lampyridæ [T. Belt]." This is doubtless one of the species mentioned by Belt in his book, and I had great hopes of being able to match it with a definite species of Lampyrid beetle, but the most diligent search through the Godman-Salvin collections of Central American insects failed to reveal a "model" to the cockroach. The Malaco-dermatous appearance is undoubtedly but generalised, not specific. The same may be said of *Hyphnorna amœna* Sauss. & Z., also from Central America. This Blattid has all the appearance of a small Longicorn, but it actually resembles no particular species of that family. It may, of course, be argued that further collecting will bring to light species of beetles which can legitimately be regarded as models to the cockroaches, but I do not think that this is in the least degree probable. Our knowledge of the Central American Coleoptera must now be nearly complete, speaking from the point of view of the systematist, and the West African *Eustegasta buprestoides* is so very abundant that it might reasonably be expected that its supposed model would be, if not abundant, at any rate in sufficient numbers to permit of some specimens falling into the hands of collectors. At the very end of this paper I describe two new species of Blattidæ, belonging to a new genus, which also must fall into the category of generalised Coleopterous mimics.

The two species of the Oriental genus *Thyrsocera* Burm. are shining black cockroaches with large yellow spots on the tegmina, a type of coloration frequently met with amongst the Endomychidæ of the same region. These cockroaches, though far larger than, and in other points quite unlike any Endomychidæ known to science, may possibly be regarded as part of a "convergent group," the dominant or "central" members of which are the yellow-spotted Endomychidæ (genus *Eumorphus*). A generalised resemblance to certain families of Rhynchota is also shown by some Blattidæ. For example, some species of *Holocompsa* Burm. and *Hypercompsa fieberi* Br. are rather like small Capsidæ; the illusory effect is produced by the tegmina, which are largely membranous and hyaline, though opaque and coriaceous at the base; the resemblance does not bear a very close examination. *Homopteroidea nigra* Shelf. is not unlike some small Fulgorid or Jassid. Mr. J. C. Kershaw found at Hong-Kong, under a stone, several little black Pentatomids, and in company with these a similarly coloured and shaped cockroach which appears to be identical with *Pseudophyllodromia parilis* Walk., and he suggested* that the cockroach mimics the bug. Having seen the specimens I prefer to regard them as examples of syncryptism or of homoplasy.

Linnaeus, deceived by the Coleopterous appearance of *Corydia petiverana*, placed it in his genus *Cassida*. Mr. T. Bainbrigge

* In a letter to Professor Poulton.

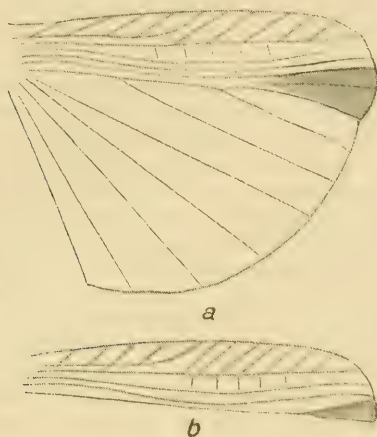
Fletcher, who has watched this insect in a state of nature in Ceylon, tells me that when it is flying it looks very like a conspicuous Agaristid moth, *Mimeusemia ceylonica* Hmps. The resemblance is certainly not very striking when the dried insects are seen side by side in a cabinet, but no field-naturalist will attach very much importance to that, and in any case Mr. Fletcher does not maintain that the resemblance is detailed and accurate, but merely generalised.

The power which the females of species of *Perisphaeria* and *Pseudoglomeris* have of rolling themselves up into spherical balls when alarmed is well known, and on account of their convex form and black shining colour, they undoubtedly bear an extremely close resemblance to the pill-millipedes which are so abundant in the tropics. But here again I doubt if any particular species of millipedes are copied. It is certainly a fact that whilst two species of *Perisphaeria* were not infrequently met with in Sarawak, both rather small, black species, I never once found a millipede corresponding in size or colour to them. It is by no means certain that the pill-millipedes are distasteful animals—on the contrary, it is quite probable that they are palatable but well protected by their hard integuments and power of rolling up into a ball. The same habit is shown by many terrestrial Isopoda, but no one considers that the Isopods mimic the Millipedes or the Millipedes the Isopods. The similarity of habit and form is attributed to homoplasy, and I see no reason why the same habit of the cockroaches should not also have been quite independently evolved.

Having now passed in rapid review the principal genera of Blattidæ which show a more or less generalised resemblance to insects of other orders, it only remains to consider in greater detail the genus *Prosoplecta* Sauss., nearly all the members of which present a remarkably close and detailed resemblance to definite specific models amongst the Coleoptera, so far as these have been discovered. With but two exceptions the species of *Prosoplecta* present an appearance which is conveniently summarised as Coccinelliform; that is to say, the outline of the body is oval verging on spherical, the form is markedly convex, the integuments are smooth and nitid, the tegmina are corneous with obsolescent venation and do not extend beyond the apex of the abdomen, the legs and antennæ are short and, finally, the insects are gaily coloured. It is scarcely necessary to point out that the Coccinelliform type is found amongst other families of Coleoptera besides the Coccinellidæ; it is found, for example, amongst the Cassididæ, Chrysomelidæ, and Galericidæ, whilst many of the Scutelleridæ, a family of Hemiptera, also present much the same facies. The two species, *P. coccinella* Sauss. and *P. bipunctata* Br., are, in spite of the name of the first, far less Coccinelliform than the other species of the genus, and may certainly be regarded as more primitive. The form is more depressed, and I am inclined to suppose that these two species,

though distinctly Coleopterous in appearance, fall into the category of generalised beetle-mimics.

Text-fig. 42.



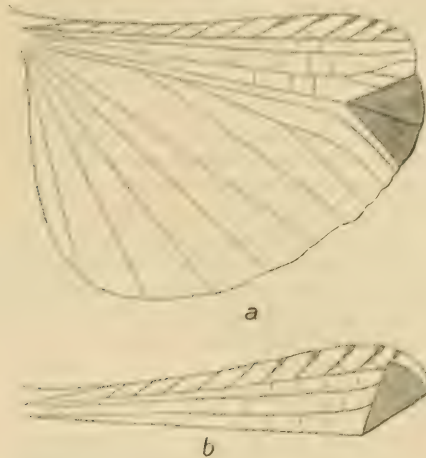
Hemithyrsocera sp.

Wing expanded (*a*) and folded (*b*). The apical triangle is shaded.

In the genus *Prosoplecta* the wings have been modified in a very remarkable manner, and as their structure has never been properly described and is of particular interest when considered together with the mimetic resemblances of the genus, it is necessary to go now into some details of the cockroach wing-structure. The wing of a cockroach such as *Blattella germanica* L., is divided longitudinally into an anterior and a posterior part; the anterior part is more or less rigid, being strengthened by numerous longitudinal and transverse veins, while the larger posterior part is supplied only with radiating longitudinal veins. When the wing is closed the posterior part shuts up like a fan and folds underneath the anterior part, which remains stiff and unfolded. At the apex of the line of division between the anterior and posterior parts of the wing is a quite inconspicuous area which, when the wing is closed, appears as a minute fold lying on the top of the anterior part. This insignificant area, which belongs neither to the anterior nor to the posterior part of the wing, is the forerunner of a part of the wing, which in some genera of Blattidae assumes relatively enormous proportions. In the genus *Hemithyrsocera* (text-fig. 42) this area has increased in size and is conspicuous enough to have attracted the attention of systematists, ever on the look out for characters diagnostic of the difficult genera of the subfamily Pseudomopinae. The area is now known as the triangular apical area, or more

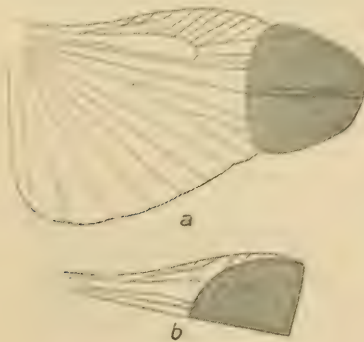
simply, the apical triangle. In the genera *Ectobius*, *Theganopteryx*, and *Chorisoneura*, to select but three examples from many, the apical triangle is still larger, has clearly defined boundaries, and in the closed wing appears either rolled up in a

Text-fig. 43.

*Chorisoneura taeniata* Sauss. & Z.

Wing expanded (a) and folded (b). The apical triangle is shaded.

Text-fig. 44.

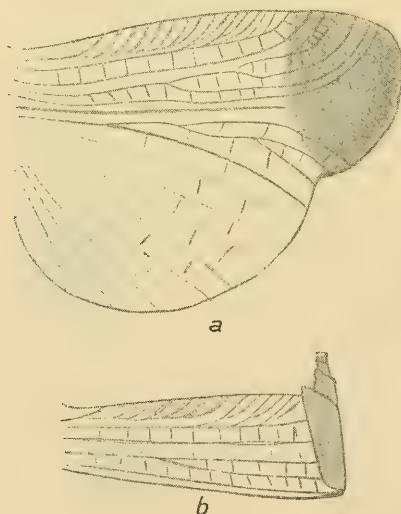
*Anaplecta decipiens* Sauss. & Z.

Wing expanded (a) and folded (b). The apical area is shaded.

spiral (*Ectobius* and *Theganopteryx*) or as a doubled fold (*Chorisoneura*), lying on the top of the anterior part of the wing (text-fig. 43). Between this stage of wing-development and that

of the genera *Anaplecta* and *Plectoptera* there is every grade of transition. In a typical species of *Anaplecta* the apical triangle has become a large parabolic area, now known as the apical area, almost equal in size to the rest of the wing, over which it is doubled back when the wing is folded (text-fig. 44). In the species *Anaplecta variipennis* Shelf., the passage from an apical triangle to an apical area can be traced; for some individuals exhibit the *Chorisoneura* type of wing-structure; in others is seen the extension of the apical triangle by the widening out of the angle made by the intercalation of this area between the anterior and posterior parts of the wing; finally, some specimens exhibit the complete development of the apical area, with its straight base-line, cutting the wing transversely into two halves, so that the longitudinal veins of the anterior part of the wing and the first axillary veins of the posterior part, no longer impinge on the outer margin of the wing, but on the base-line of the apical area. The summit of wing-development is attained by *Diploptera dytiscoides* Serv., for in this species the apical area is closely veined, though the veins are not in organic continuity with those of the other part of the wing.

Text-fig. 45.

*Prosoplecta nigrovariegata*.

Wing expanded (a) and folded (b). The pseudapical area is shaded.

A cursory glance at the closed wing of any species of *Prosoplecta* (text-fig. 45) leads the observer to suppose that it is constructed on the same principle as that of *Ectobius* and *Thegan-*

opteryx, for there is visible a large curled-up spiral lying on the dorsal face of the anterior part of the wing. But when the wing is spread out it is seen that the method of wing-folding is quite peculiar. The triangular apical area though large is not sharply defined as in *Chorisoneura*, *Theganopteryx*, etc., and the spiral fold involves not only this area but also the apical portion of the anterior part of the wing, and a minute portion of the apex of the posterior part. The part of the wing involved in the spiral fold constitutes in fact a *pseud-apical area*, and it is suffused with a dark fuscous colour, just as the true apical area of *Anaplecta* and the apical triangle of *Chorisoneura* etc. are coloured more deeply than the other parts of the wing.

There can be little doubt that this type of wing-folding, unique amongst the Blattidæ, is a modification brought about by the mimetic resemblance, and it is certainly a very singular one. The student of the mimetic resemblances which exist between insects not genetically related, frequently comes across remarkable modifications of structure, modifications which are alien, so to speak, to the constitution of the insects; here a concentration of pilosity to form a false spine, there a patch of colour, a shortening of elytra, or a thickening of legs or antennæ. But invariably he will find these are modifications of structure absolutely essential to the success and perfection of the mimicry; if he looks deeper he will find that mimicry has not touched parts which are concealed, and which therefore play no part in the mimetic resemblance. In short, mimicry is essentially a superficial likeness between organisms fundamentally different. Yet here in the species of *Prosoplecta* we have an exception to this very general rule. The wing of the cockroach does not mimic the wing of the beetle, but it has been modified because of the mimicry between the two orders of insects, or in other words, in this case mimicry *has* affected structures which play no part in a mimetic resemblance. To speak in the crudest of metaphors, it appears as if in the production of these Coccinelliform cockroaches Nature had been in a tremendous hurry. The immediate ancestors of *Prosoplecta* were probably narrow and moderately elongate cockroaches with wings of the *Hemithyrsochera* type; passage from this form to a short convex form might have proceeded along at least two lines—either the wings might have become gradually shorter *pari passu* with the tegmina, as in certain species of *Ceratinoptera*, *Allacta*, etc., or the wings could have been adapted to an ovate, abbreviated body-form by passing through a *Chorisoneura*-like stage to the *Anaplecta* type. As a matter of fact the evolution of *Prosoplecta* did not travel along either of these lines,—the necessary shortening of the wing when in repose has been produced by a rolling up of as much of the wing as was necessary for the purpose, quite independently of the boundaries between the intercalated apical triangle and the rest of the wing, and so in defiance of the rule observed in all other species of the family.

The geographical distribution of *Prosoplecta* is as follows:—Eight of the species are found in the Philippine Islands, one in Celebes, the remaining three in Batchian and Ceram. None has yet been discovered in the Great Sunda Islands, so that the distribution is discontinuous and serves to emphasize the view that if the Philippines are to be regarded as a part of the Indo-Malayan region, their separation from adjacent land is of very great antiquity. The Philippine Islands constitute an area in which insect mimicry has attained great perfection. That is shown not only by these wonderful cockroaches mimicking Coleoptera, but Professor Poulton tells me that some of the most wonderful examples of mimicry amongst butterflies are known from these islands only, *e.g.* the distasteful Danaine genus *Hestia* is mimicked very closely by a Satyrine and an Elymniine. Again, the gorgeous little Curculionidæ of the genus *Pachyrhynchus* are mimicked by other weevils, by Longicorns, by Cetoniids, and by a cricket*. A comparative study of mimetic insects in geographically adjacent but zoologically distinct areas, such as Borneo, the Philippines, and Celebes, is a piece of research that would surely yield some very interesting results.

I now give a synoptical key to the genus *Prosoplecta* with descriptions of all the species known to me. It will be observed that I have not always been able to pair a species of *Prosoplecta* with a definite Coleopterous model, but I am pretty confident that these models will eventually be found. I have not had access to comprehensive collections of Philippine Coleoptera, and so it is chiefly the Philippine *Prosoplectæ* which for the present I am not able to match. It is unfortunate that Semper's collection of Philippine Coleoptera is broken up and dispersed; Stål purchased his Orthoptera for the Stockholm Museum, and here it was that I found four new species of *Prosoplecta*, but the Coleoptera captured at or about the same time and in the same districts, I have not been able to trace.

Key to the Species of Prosoplecta.

- | | |
|--|-----------------------------|
| 1. Less convex species. Tegmina with a smooth flattened tubercle near the middle of the anal vein. | |
| 2. Pronotum piceous, margined all round with hyaline testaceous | <i>P. coccinella</i> Sauss. |
| 2'. Pronotum bright rufous | <i>P. bipunctata</i> Br. |
| 1'. Very convex species. Tegmina without flattened tubercles. | |
| 2. Ground colour of tegmina ochreous or rufous. | |
| 3. Tegmina maculate. | |
| 4. Maculæ of tegmina piceous. | |
| 5. Tegmina deeply punctate. (Pronotum with 4 maculæ.) | <i>P. trifaria</i> Walk. |

* Semper in his 'Animal Life,' p. 390 (International Scientific Series, 1890) gives figures of some of these mimetic insects, amongst them one with the legend "Phoraspis (grasshopper) mimics a Coccinella." This is an error, for the Phoraspis is a cockroach, apparently identical with *Prosoplecta ligata* Br. The species described below as *P. semperi* is a much better mimic of the Coccinellid figured by Semper than is *P. ligata*. Semper's figures (and error) are reproduced by Dr. Wallace in his 'Darwinism.'

- 5'. Tegmina not deeply punctate.
 6. Ground colour of tegmina ochreous *P. nigroplagiata*, sp. n.
 6'. Ground colour of tegmina rufous..... *P. semperi*, sp. n.
 4'. Maculæ of tegmina ochreous..... *P. rufa* Kirby.
 3'. Tegmina immaculate, margined with piceous . *P. ligata* Br.
 2'. Ground-colour of tegmina piceous or dark castaneous.
 3. Tegmina with not more than 4 rufous or ochreous maculæ.
 4. Tegmina distinctly punctate..... *P. quadriplagiata* Walk.
 4'. Tegmina indistinctly punctate..... *P. nigra*, sp. n.
 3'. Tegmina with more than 4 rufous or ochreous maculæ.
 4. Pronotum ochreous with 5 piceous maculæ . *P. gutticollis* Walk.
 4'. Pronotum piceous with the lateral margins hyaline ochreous.
 5. Maculæ on tegmina ochreous, more or less circular *P. minas*, sp. n.
 5'. Maculæ on tegmina rufous, more or less band-like *P. calophoroides*, sp. n.

PROSOPECTA COCCINELLA Sauss. (Pl. XLVIII. fig. 5.)

Prosoplecta coccinella Saussure, Rev. Zool. (2) xvi. p. 324 (1864); Mém. Mexique, Blatt. p. 173 (1864).

♀. Head castaneous, vertex paler. Antennæ castaneous at base, remainder fuscous. Pronotum transversely elliptical, with the disc piceous, punctate, all the margins testaceo-hyaline. Tegmina dark castaneous, seriate-punctate; mediastinal area testaceo-hyaline; a minute, smooth, flattened tubercle at the humeral angle, a smaller one near the base of the radial vein and a larger one in the centre of the disc near the middle of the obsolete anal vein, testaceous. Wings infuscated, veins castaneous. Abdomen above fuscous, supra-anal lamina margined with testaceous, sub-bilobate; abdomen beneath piceous, nitid, sub-genital lamina very large, semiorbicular. Cerci short. Legs castaneous.

Total length 8-9 mm.; length of tegmina 6.2 mm.; pronotum 2.5 mm. × 3.5 mm.

PHILIPPINE IS. (Paris Mus., *type*; British Mus.; Oxford Mus.).

The species is not coccinelliform, but is more like a little Chrysomelid.

PROSOPECTA BIPUNCTATA Br. (Pl. XLVIII. fig. 2.)

Areolaria bipunctata Brunner von Wattenwyl, Nouv. Syst. Blatt. p. 261 (1865).

♀. Very similar to the preceding species, but the head is bright rufous, the palpi and the bases of the antennæ are piceous, remainder of antennæ clear testaceous. Pronotum rufous, lateral margins testaceo-hyaline, posterior margin opaque testaceous, with a fuscous line at the posterior angle. Tegmina piceous with mediastinal area testaceous, a flattened smooth tubercle, testaceous in colour, in the same position as the largest one in *P. coccinella*. Abdomen piceous above and beneath, faintly margined with testaceous. Coxæ and femora rufous, tibiæ and tarsi castaneous.

Total length 8.5 mm.; length of tegmina 6.5 mm.; pronotum 2 mm. \times 3.5 mm.

PHILIPPINE Is. (Stettin Mus., *type*; Stockholm Mus., *coll. Semper*).

This species is also like a Chrysomelid.

PROSOPECTA TRIFARIA Walk. (Pl. XLVIII. figs. 4 & 11.)

Prosoplecta trifaria Walker, Cat. Blatt. Brit. Mus. p. 190 (1868) [= ♂].

Prosoplecta megaspila Walker, l. c. (1868) [= ♀].

Very convex, bright ochreous with piceous maculæ on pronotum and tegmina.

♂. Head and antennæ ochreous, a blotch on the frons, the labrum and apices of maxillary palpi, fuscous. Pronotum nitid, impunctate, transversely elliptical, with four small piceous maculæ on the disc. Tegmina seriate-punctate, a line between the bases of the radial and mediastinal veins, a short line above the humeral angle (which is pronounced), the inner margin of the left tegmen at the base, the portion of the right tegmen overlapped by the left and a round macula in the anal field, piceous. Wings infuscated. Abdomen above and beneath and the legs ochreous. Sub-genital lamina symmetrical with a median plication, posteriorly emarginate, styles minute. Cerci moderate.

♀. Similar, but the piceous markings on the tegmina heavier, and a large additional macula on the discoidal field beyond the middle. The abdomen beneath is castaneous, and the sub-genital lamina is very large and semiorbicular.

Total length (♂) 9 mm., (♀) 9.5 mm.; length of tegmina (♂) 7.5 mm., (♀) 8.1 mm.; pronotum 3 mm. \times 4 mm.

BATCHIAN (Oxford Mus., *types, coll. Wallace*).

The male is an admirable mimic of *Oides biplagiata*, and the female resembles a dark variety of the same insect (Chrysomelidæ, subfam. Galerucinæ). (Pl. XLVIII. figs. 3 & 10.)

PROSOPECTA NIGROPLAGIATA, sp. n. (Pl. XLVIII. fig. 9.)

♀. Allied to *P. trifaria*, but distinguished by the obsolescent puncturation of the tegmina. Head rufous, vertex ochreous. Antennæ very slender, ochreous, with the apex infuscated. Pronotum ochreous, smooth, nitid, transversely elliptic, lateral margins hyaline, eight piceous maculæ arranged in a circle on the disc, the anterior pair almost fused, one pair minute. Tegmina ochreous, extreme base of mediastinal area hyaline, a macula at the base of the mediastinal area, a macula at the apex of the same area, a line joining these, a round macula on the middle of the anal vein, a curved line running from this over the humeral angle to the base of the tegmen, where there is another spot, the basal margin, a short line along the base of the sutural margin of the right tegmen, a large macula in the discoidal field beyond the middle, all piceous. Wings infuscated. Abdomen beneath rufo-castaneous, sub-genital lamina very large, semiorbicular. Cerci and legs rufous.

Total length 9·5 mm.; length of tegmina 7·9 mm.; pronotum 3 mm. × 5 mm.

PHILIPPINE IS. (Stockholm Mus., *type, coll. Semper*).

This species is a good mimic of *Prioptera sinuata* Oliv. (Cassididæ), and it is highly probable that a Coccinellid and perhaps a Chrysomelid also enter into mimetic relationship with these forms. (Pl. XLVIII. fig. 8.)

PROSOPECTA SEMPERI, sp. n. (Pl. XLVIII. fig. 13.)

♀. Differs from *P. nigroplagiata* in the following details:—Size larger and broader; the general ground colour is rufous; there are only six maculæ on the disc of the pronotum, the anterior pair being suppressed; on the tegmina there are no lines joining any of the maculæ, the maculæ are as in *nigroplagiata*; there is an ellipsoidal piceous marking on the part of the right tegmen overlapped by the left; the disc of the subgenital lamina is suffused with castaneous.

Total length 10·5 mm.; length of tegmina 7·8 mm.; pronotum 3 mm. × 5·8 mm.

PHILIPPINE IS. (Stockholm Mus., *type, coll. Semper*).

Mimics *Leis dunlopi* Crotch (Coccinellidæ). (Pl. XLVIII. fig. 12.)

PROSOPECTA LIGATA Br.

Cassidodes ligata Brunner von Wattenwyl, Nouv. Syst. Blatt. p. 262, pl. vi. fig. 28 (1865).

The species is known to me only from the description, which it is unnecessary to reproduce, since it occurs in the vade-mecum of all students of the Blattidæ.

PHILIPPINE IS. (Stettin Mus., *type*).

PROSOPECTA RUFA Kirby*. (Pl. XLVIII. fig. 16.)

Prosopecta rufa Kirby, Ann. Mag. Nat. Hist. (7) xii. p. 379 (1903).

This species is known to me only from the description, which I transcribe:—

“Long. corp. cum tegm. 9 millim.; lat. 5 millim.

“*Female*.—Light red, the tegmina somewhat darker. Pronotum smooth and shining, with the front border narrower than the hind border, transversely oval, with broad borders of subhyaline yellow covering the rounded off lateral angles, and the hind border yellow. Tegmina with the costal margin subhyaline yellow, a small yellow spot near the base, and another at one third of the length, both near the costa; between the second and the inner margin is a much larger, transverse, oval, yellow spot. Base of tegmina blackish. Wings, and a great portion of the middle of the abdomen beneath, as far as the base of the terminal segment, black.”

PHILIPPINE ISLANDS, Mindanao (British Mus., *type*).

* It is probable that *P. rufa* is identical with *P. bipunctata*, a discovery made long after this paper was in the press. The extreme difficulty under which the paper was written must be my excuse.

PROSOPECTA QUADRIPLAGIATA Walk. (Pl. XLVIII. fig. 14.)

Prosoplecta quadriplagiata Walker, Cat. Blatt. Brit. Mus. p. 189 (1868).

♂. Head castaneous, antennæ rufo-testaceous. Pronotum piceous, smooth, nitid. Tegmina seriate-punctate, piceous, an orange-rufous macula at the base, another in the centre of the discoidal field. Wings fuscous. Abdomen above and beneath rufous; supra-anal lamina transverse, carinate, apex emarginate; sub-genital lamina as in *P. trifaria*. Cerci and legs rufous.

Total length 9·5 mm.; length of tegmina 8 mm.; pronotum 2·8 mm. × 4·5 mm.

BATCHIAN (Oxford Mus., *type, coll. Wallace*).

Somewhat resembles an Erotylid of the genus *Aulacoechilus* or *Cyrtomorphus*.

PROSOPECTA NIGRA, sp. n. (Pl. XLVIII. fig. 6.)

♂. Head rufo-testaceous, antennæ testaceous. Pronotum castaneous, impunctate, nitid, faintly striate transversely in the middle of the anterior half. Tegmina very faintly punctate, piceous, an orange rufous macula at the apex. Wings infuscated. Abdomen above and beneath rufous; supra-anal lamina transverse; sub-genital lamina as in the preceding species. Cerci and legs rufous.

Total length 9 mm.; length of tegmina 7·8 mm.; pronotum 2·9 mm. × 4·2 mm.

PHILIPPINE IS. (Stockholm Mus., *type, coll. Semper*).

The species is closely allied to *P. ligata* Br., and is probably a mimic of some Chrysomelid beetle.

PROSOPECTA GUTTICOLLIS Walk. (Pl. XLVIII. fig. 7.)

Prosoplecta gutticollis Walker, Cat. Blatt. Brit. Mus. p. 189 (1868).

♀. Head rufo-castaneous, paler on the vertex; antennæ testaceous, fuscous towards apex. Pronotum smooth, nitid, ochreous, lateral margins subhyaline, five piceous maculae on the disc. Tegmina seriate-punctate, piceous, with the following large ochreous maculae on each tegmen:—one in the mediastinal area, one in the middle of the marginal area, one at the base of the tegmen almost divided into two by a short piceous line on the humeral angle, and at its lower interior extremity just touching a macula in the middle of the discoidal field, a fifth macula near the apex of the tegmina. Abdomen above ochreous; supra-anal lamina triangular, cucullate, apex not emarginate. Abdomen beneath piceous, castaneous at base; sub-genital lamina semiorbicular, ample. Cerci and legs rufous.

Total length 9·5 mm.; length of tegmina 8·5 mm.; pronotum 3·1 mm. × 5 mm.

CERAM (Oxford Mus., *type, coll. Wallace*).

Very like a Coccinellid.

PROSOPLECTA MIMAS, sp. n. (Pl. XLVIII. fig. 15.)

♂. Head rufous, vertex paler; antennæ testaceous, infuscated towards apex. Pronotum smooth, nitid, piceous, lateral margins broadly hyaline, a large ochreous macula at the posterior angles, enclosing three minute piceous spots, a minute V-shaped ochreous mark in the middle near the posterior margin. Tegmina minutely seriate-punctate, piceous, with the following ochreous maculæ on each tegmen:—one in the mediastinal area, one in the anal area extending on to the humeral angle, one in the middle of the discoidal field, one outside this and touching the radial vein, one at the apex, that on the left tegmen being larger than that on the right. Wings infuscated. Abdomen beneath, cerci and legs rufous, subgenital lamina as in the other species of the genus.

♀. Similar to the male but the head and abdomen darker, the macula in the anal field of the tegmina almost divided into two, two maculæ at the apex of the left tegmen. Supra-anal and subgenital laminæ as in the preceding species.

Total length (♂) 8.9 mm., (♀) 10.9 mm.; length of tegmina (♂) 7 mm., (♀) 9 mm.; pronotum (♂) 2.9 mm. × 4.6 mm., (♀) 3 mm. × 5 mm.

PHILIPPINE IS. (Stockholm Mus., types, coll. Semper).

PROSOPLECTA CÆLOPHOROIDES, sp. n. (Pl. XLVIII. fig. 19.)

♂. Head castaneous, vertex ochreous; antennæ testaceous, fuscous towards the apex. Pronotum impunctate, nitid, piceous with the lateral margins broadly ochreous. Tegmina seriate-punctate, piceous, with the following rufous maculæ on each tegmen:—a small circular one in the mediastinal area, a transverse one extending along the base of the tegmen over the humeral angle to the base of the radial vein, another broadly transverse extending across the middle of the discoidal field from near the sutural margin to the radial vein, a fourth circular in shape, near the apex of the tegmen. Wings infuscated. Abdomen and legs rufous; supra-anal lamina of usual shape.

Total length 9.2 mm.; length of tegmina 8 mm.; pronotum 3 mm. × 4.9 mm.

NORTH CELEBES, Toli-Toli (Oxford Mus., type, Fruhstorfer, c. coll. Van de Poll).

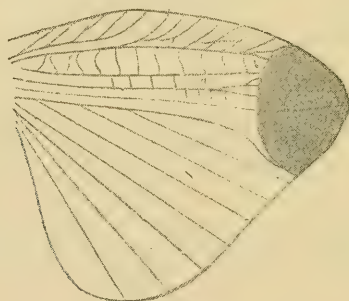
This is an admirably close mimic of the Coccinellid *Cælophora formosa* Cr. (Pl. XLVIII. fig. 21), a specimen of which was taken by Fruhstorfer in the same locality and at the same time of year. The colouring and arrangement of the maculæ on the pronotum and wing-covers of the two insects correspond very closely, but in the beetles there is a transverse basal band on the elytra, whereas in the cockroach the corresponding patch of colour is made up of a band-like spot and an outer circular spot. The mimic is smaller than its model, and that appears to be rather the rule than the exception amongst this group of mimetic couples. *Anisolemmia distaura* Muls. (Pl. XLVIII. fig. 20) is another Coccinellid of nearly the same size and evidently also associated.

Description of a new Genus and two new Species of Blattidæ.

Genus MELYROIDEA, nov.

Head semiglobose, eyes small, far apart, situated on the sides of the head; antennæ with moniliform joints, slightly incrassated, not pilose, third joint twice as long as second. Pronotum quadrate, angles rounded, margins somewhat reflexed, not covering the vertex of the head; disc with slight elevations and depressions. Tegmina densely reticulated, obscuring the venation, semi-corneous in texture, anal field scarcely distinguishable; scutellum exposed. Wings with moderate apical field, which in repose is doubled on itself longitudinally and tightly rolled up, not folded back over the rest of the wing; traces of venation in the lower half of the apical field. Supra-anal lamina of female triangular or trigonal; sub-genital lamina divided by a sulcus; cerci variable. Legs slender, all the femora unarmed, tibiæ very sparsely spined, tarsi without arolia. Male unknown.

Text-fig. 46.

*Melyroidea mimetica.*

Expanded wing. The apical area is shaded.

This is quite one of the most remarkable genera of Blattidæ that has yet been discovered. The two species comprised in it present in their form and coloration a curious resemblance to Malacoderm Coleoptera, whilst in their structural features they appear to be intermediate between the Corydiinæ and Oxyhaloinæ [= Plectopterinae]. The head with its globose front and vertex and widely separated eyes of small size, the cleft sub-genital lamina of the female, and the naked tarsal claws are characteristic features of the Corydiinæ. On the other hand, the wing-structure is totally unlike that of the Corydiinæ, in which subfamily alone amongst the Blattidæ the anterior part of the wing is greatly developed, the posterior part folding beneath not in a fan-like manner. In *Melyroidea* the wing with its prominent apical area and posterior part furnished with radiating veins is

typically Plectopterine in structure, and this character, in conjunction with the fan-like folding of the posterior part of the wing, is overwhelming evidence in favour of the inclusion of the genus in the Oxyhaloinæ [=Plectopterinae].

MELYROIDEA MIMETICA, sp. n. (Pl. XLVIII. fig. 17.)

♀. Head bright rufous, last joint of maxillary palpi fuscous, antennæ fuscous, except the basal and last apical joints, which are rufo-testaceous. Pronotum bright rufous, quadrate, anterior and lateral margins slightly reflexed, sides only slightly deflexed; disc with slightly rounded elevations, two anterior, two antero-lateral, and one, the largest, central. Tegmina dark castaneous, densely reticulated, mediastinal vein short, an oblique sulcus on the right tegmen marking the outer limit of the area overlapped by the left tegmen. Wings infuscated, radial vein bifurcated from the base, twelve costal veins, apices not incrassated, median vein simple, medio-discal area crossed by fourteen irregular venulæ, thrice as broad as the medio-ulnar area, which is crossed by eleven venulæ, ulnar vein bifurcate, transverse venulæ connecting it with the dividing vein, first axillary vein trimorse; apical area about one third of total wing-length, its base obtusely angled, nearly equally divided longitudinally, some obscure venulations in the lower half. Abdomen piceous above and beneath, supra-anal lamina triangularly produced, sub-genital lamina cleft by a sulcus; cerci short, acuminate, rufous. Coxæ, femora, and bases of tibiæ testaceous, rest of tibiæ and the tarsi fuscous; formula of apical spines $\frac{1}{1}, \frac{0}{0}, \frac{0}{0}$, genicular spines on mid and hind femora; front tibiæ unarmed except for three apical spines, mid and hind tibiæ with one pair of basal and two apical spines above, with ten spines in a double row and two apical spines below.

Total length 13.5 mm.; length of body 11 mm.; length of tegmina 9.5 mm.; pronotum 4 mm. × 4 mm.; hind femora 4 mm.; hind tibiæ 4 mm.; hind tarsi 3 mm.

Hab. Uncertain, but probably near RIO DE JANEIRO.

One example (Miers collection. Oxford Museum).

The species is very like a Telephorid beetle.

MELYROIDEA MAGNIFICA, sp. n. (Pl. XLVIII. fig. 18.)

♀. Head bright rufous, maxillary palpi piceous, antennæ piceous, except for three joints beyond the middle, which are testaceous, slightly incrassated in the middle. Pronotum bright rufous, quadrate, very slightly broader anteriorly than posteriorly, all the borders somewhat reflexed, disc with two antero-lateral crescentic depressions. Tegmina green, the humeral angle and the part of the right tegmen overlapped by the left dark shining blue, densely reticulated but the veins elevated, mediastinal vein short, radial vein bifurcated from near the base, six highly irregular and branched costal veins, ulnar vein with three ramose branches, apex of anal vein attaining a point at

more than one third of the sutural margin. Wings very dark fuscous. Abdomen, cerci, and legs dark blue with metallic reflections, supra-anal lamina trigonal, sub-genital lamina cleft and valvular in appearance; cerci very long, with sparse erect pubescence, not acuminate. Formula of apical spines $\frac{1}{0}, \frac{0}{0}, \frac{0}{0}$, no genicular spine on front femora; front tibiae with three apical spines and one spine beneath, mid and hind tibiae with two widely separated spines above, four apical spines and a double row of spines beneath.

Total length 14 mm.; length of body 11 mm.; length of tegmina 11.5 mm.; pronotum 2.8 mm. \times 3 mm.

ECUADOR.

One example (Saunders collection, Oxford Museum).

This gorgeous little cockroach is also very like a Telephorid, but I have not been able to match it with any particular species.

In the preparation of this paper I have been much indebted to the kind assistance of my friend, Mr. G. J. Arrow, who has diligently searched the rich collections of Coleoptera in the British Museum for models to some of the remarkable mimetic cockroaches described above. Mr. Arrow has also supervised the preparation of the plate accompanying this paper.

EXPLANATION OF PLATE XLVIII.

Fig. 1. *Megapyga eximia* Boh.

2. *Prosoplecta bipunctata* Br.

3. *Oides biplagiata* Jac.

4. *Prosoplecta trifaria* Walk., ♂.

5. *P. coccinella* Sauss.

6. *P. nigra*, sp. n.

7. *P. gutticollis* Walk.

8. *Prioptera sinuata* Oliv.

9. *Prosoplecta nigroplagiata*, sp. n.

10. *Oides biplagiata* Jac., var.

11. *Prosoplecta trifaria* Walk., ♀.

Fig. 12. *Leis dunlopi* Crotch.

13. *Prosoplecta semperi*, sp. n.

14. *P. quadriplagiata* Walk.

15. *P. mimas*, sp. n.

16. *P. rufa* Kirby.

17. *Melyroidea mimetica*, sp. n.

18. *M. magnifica*, sp. n.

19. *Prosoplecta cælophoroides*,
sp. n.

20. *Anisolemnia distaura* Muls.

21. *Cælophora formosa* Crotch.

20. On the Pairing of Pseudoscorpiones.

By H. WALLIS KEW, F.Z.S.

[Received January 20, 1912: Read February 6, 1912.]

(Text-figures 47-50.)

I. Introduction.

The breeding habits of Arachnida are of special interest from the fact that in no other Class do we find so great a diversity of method*. Much attention has been paid to the subject, and the main facts are established for most of the Orders. For Pseudoscorpiones, however, scarcely anything is known.

Rösel von Rosenhof, so long ago as 1755 (1), tells us that he kept these animals together for a long time in the hope of seeing

* Cf. Pocock (19), p. 2.

their pairing, yet without success. So also McIntire (5), who had great experience with several species in captivity, watched patiently for amiable traits, but all in vain. Schtschelkanowzeff, in fact, appears to be the only author who has seen the pairing of any animal of this Order. He states, in a memoir published in 1910 (17), that he saw this act frequently in a species of *Chelifer* (*Chernes*); and he has established the fact that fertilization is effected without intromission of a copulatory organ. But he did not see exactly what took place; and the remarkable details of the process remain, it is believed, quite unknown.

Mr. R. I. Pocock called the writer's attention to this subject in 1903, since which time a careful watch has been kept on these animals, both in the open and in captivity.

The captive individuals, it may be explained, were housed in what are known as "McIntire cells"; that is to say, in little cases about three inches long, an inch or so broad, and a quarter of an inch or less high. The body was of sheet-cork, the floor of glass covered with blotting-paper, and the roof of clear glass; the whole being held together by rubber-bands. The glass forming the roof was transversely cut and hinged, so that food and moisture could be readily administered*. In these abodes the animals lived in health for a long time, and they were easily watched both under low powers of the microscope and with a lens. Observation was facilitated, it may be added, by the animals walking on the under surface of the roof, so as to expose to view the genital area, which occupies in this Order the usual position at the base of the abdomen.

The sexes meet in ordinary walking position head to head, and, after some preliminary fencing, the male manages to grasp with one or both of the hands of the palps one or both of the hands of the palps of the female. Early observations showed this to be the case in *Chelifer cinicoides* Fabr.†, whose pairing, however, has not yet been fully made out. Similar behaviour was afterwards witnessed in the relatively gigantic *Chelifer cyrneus* L. Koch, and it was on this species that most of my observations were made. First of all, however, something must be said of *Chelifer latreillii* Leach, an animal subgenerically distinct from those just named and one of considerable interest in many respects.

II. Pairing of *Chelifer latreillii* Leach.

Chelifer latreillii, always maritime in Britain, ranges with us from Fifeshire to Sussex, and is excessively abundant on the great sand-dunes of the coasts of Lincolnshire and Norfolk. In such places it makes its home for the most part in the tussocks of *Ammophila arenaria*; but it evidently moves about freely, being found often under pieces of wood, etc., on the sandy ground.

It belongs to the subgenus *Chelifer* s. s., a small group

* Cf. McIntire (4), pp. 71-2.

† For the nomenclature employed in this paper, cf. Kew (18).

remarkable for the specialization of the male, in which both primary and secondary characters are unusually pronounced*. The genital area of this sex is large and conspicuous, the first genital plate being short and of peculiar character, while the second is both long and broad, and under this latter are found two very large structures, inappropriately called ram's-horn organs, to which it will be necessary to recur. The fourth pair of coxæ, which bound the genital area anteriorly, differ much from those of the female, being strongly concave behind and containing a peculiar organ, the coxal sac of With (13). Of characters remote from the genital area there is considerable diversity within the group; there are generally remarkable modifications in the legs of the first pair, and these modifications are unusually well-marked in the present species. The whole leg is greatly strengthened, with hump-backed tarsus, and greatly enlarged claws, the anterior claw being of peculiar shape with oddly turned extremity and with a process along its anterior margin. Further, while the hand of the palp is a little smaller than that of the female, the fingers when closed at the tip have a wider gape.

The ram's-horn organs already mentioned—supposed to be tracheal in origin—have been studied in allied species by several authors†. They are concealed under the second genital plate, where they lie in a highly contracted condition. Preserved specimens, in exceptional cases, have them protruded externally; and they have been figured thus protruded by Simon (6), and after him by Tömösváry (7); and by With (16). It does not appear, however, that they have been seen in action; and the suggestion of Menge (2) and Simon (6) that they are sperm-transmitters, perhaps intermittent organs‡, is erroneous, as also is that of Schtschelkanowzeff (17), who thought they might be concerned in placing sperm-masses on the ground.

With regard to the other characters, except that With (14) and Schtschelkanowzeff (17) have supposed the coxal sac to be a sense-organ with some sexual significance, no suggestions appear to have been made. The gape of the fingers, however, is obviously connected with the grasping of hands already mentioned; and the observations now recorded show what is done with the ram's-horn organs and with the legs of the first pair.

It was in May 1905, on the sand-dunes between Sandwich and Deal, that I first saw the meeting of the sexes of this animal. On turning over a piece of tin, I found on its under surface a male and female which had approached each other head to head, and were actively fencing with the palps. The male at length disarmed the female by getting a firm grasp of the hands, which were held fast during the whole of these preliminary proceedings.

* With (14), pp. 132-3; With (16), p. 220; Kew (18), p. 47.

† Menge (2), p. 17, pl. ii. fig. 12; Hansen (8), pl. vii. fig. 2 h; Croneberg (9), pp. 456-7, pl. xi a. figs. 45-47; Bernard (10), pp. 423-6; Oudenans (15), pp. 136-140; Schtschelkanowzeff (17), pp. 6-14.

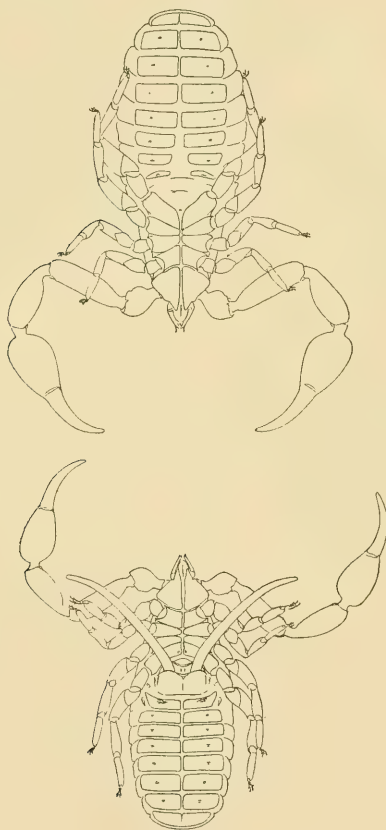
‡ On the supposed occurrence of intromittent organs in this Order, cf. Lankester (12), p. 256; and Croneberg (9), p. 39.

The animals moved considerably backwards and forwards and round about; and the male, all the time in a state of great activity, made at intervals determined advances towards the female, but he was prevented from approaching closely. On the occasion of each of these advances the male brought the ram's-horn organs into action, running them out rather rapidly to their full extent; they took at these times a forward lateral direction, their extremities usually assuming an outward curve and passing under or over the femora of the male's palps. Occasionally they touched some part of the palps of the female, but this seemed accidental. At the full extension of the organs, the male vibrated his body in a peculiar manner and had at this time a remarkable, even villainous appearance; but the organs were exposed only for a few moments, after which they ran in again rather rapidly, the male then taking a few steps backwards. Eventually the animals separated—perhaps disturbed by the sunlight to which they were exposed—without proceeding to any act of fertilization. In 1906, also in May, similar observations were made on specimens collected on the Lincolnshire coast, but again no act of fertilization was seen; and no more observations were made till the spring of 1911. In the third week of April in that year, a good number of specimens were collected on the Camber sand-hills in Sussex; and they were kept under daily observation in one of the cells above described. During the remaining days of April and the early days of May, the males, which had the abdomen rather full, seemed to have difficulty in restraining the ram's-horn organs, the tips of which constantly appeared from under the great genital plate, which was at such times raised anteriorly and depressed into the abdomen posteriorly. Many fencing contests between male and female were seen; but the male did not always obtain any advantage in the grasp and was often in fact rather roughly used; he continued, however, even at these times, to display the ram's-horn organs with great energy. As before, I failed to observe the acts of fertilization. It was evident, however, that such acts had occurred, either before or after the animals came under observation, for about a month later eggs began to appear externally on a few of the females, and in the first week of July young broods appeared. Shortly before this time, fortunately, that is to say about mid-summer, there was a recurrence of sexual activity in the cell; and on 22nd June the whole process of the passing of the male product to the female was successfully witnessed.

The animals, male and female, had taken up a position, ventral face uppermost, on the under surface of the glass; and the male, who was firmly holding both hands of the female, was making periodical advances towards her with display of the ram's-horn organs as above described. It soon became evident that the female was offering but slight resistance; the male was allowed to make a near approach, and at length he was even permitted to caress with his chelicerae the chelicerae of the female. This done, he quickly retired as before by taking a step or two backwards;

and it was now seen that as he did so the female was quite eager to take the corresponding steps forwards. As this tendency became more and more marked, the male released his grasp of the hands of the female, who was now free, at least from corporal

Text-fig. 47.

*Chelifer latreillii* Leach.

Male and female; in ventral view, seen through a piece of glass, on the under-surface of which they are standing. The position is that of the last phase of the courtship; the male has released the hands of the female, and is about to extrude the spermatophore; the ram's-horn organs are fully extended or nearly so. $\times 13$.

(The bristles and tactile-hairs are omitted.)

control. The male continued, however, to make advances and to display the ram's-horn organs even with greater energy than before; and finally, on the occasion of one of these advances—while

not in contact with the female in any way—the ram's-horn organs being fully extended (text-fig. 47), he extruded from the genital opening between the bases of these organs a large elongated structure—evidently a spermatophore*—one extremity of which became at once attached to the glass by means of a foot-like pad of quick-drying adhesive matter. The other extremity was still in contact with the genital opening of the male; and when thus freshly extruded this spermatophore bore externally, somewhat near the middle, some clouded liquid in the form of a moderately large surrounding globule. After a delay of a few moments, the male stepped backwards, and thus released the spermatophore, leaving it attached to the glass as just mentioned, but otherwise free, in an oblique position, with the unattached extremity directed towards the male. No sooner had the male thus stepped back, than the female came quickly forward till the female genital opening was in contact with the spermatophore. This forward movement of the female was accompanied, I believe, by a slight but rapid forward movement of the male; and, however this may be, the head of the male had passed under that of the female; and at the same moment, with great suddenness, the male threw forward the stout legs of the first pair and seized with them the anterior margin of the female genital opening, on which the enlarged peculiarly formed claws became firmly hooked; and now the male commenced a rather long series of violent pulling movements with these legs, by means of which the body of the female was moved on the spermatophore, a part of which had, I believe, entered the female genital opening. These movements brought the proceedings to a close, and the animals now separated, leaving the spermatophore, or at least the shell of it, still attached by its foot to the glass. No repetition of these acts was observed. Another spermatophore was found in the cell, however, towards the end of August.

Text-fig. 50 A (p. 386) shows the spermatophore from above and from below. It was of firm substance and somewhat complicated in structure. Beyond the foot of attachment it was rather slender but it gradually increased towards a neck-like constriction, beyond which was a widened head with a small horn-like point on either side; and beyond this head was a rather long narrowed extremity of definite construction. The total length was considerably more than half that of the entire animal.

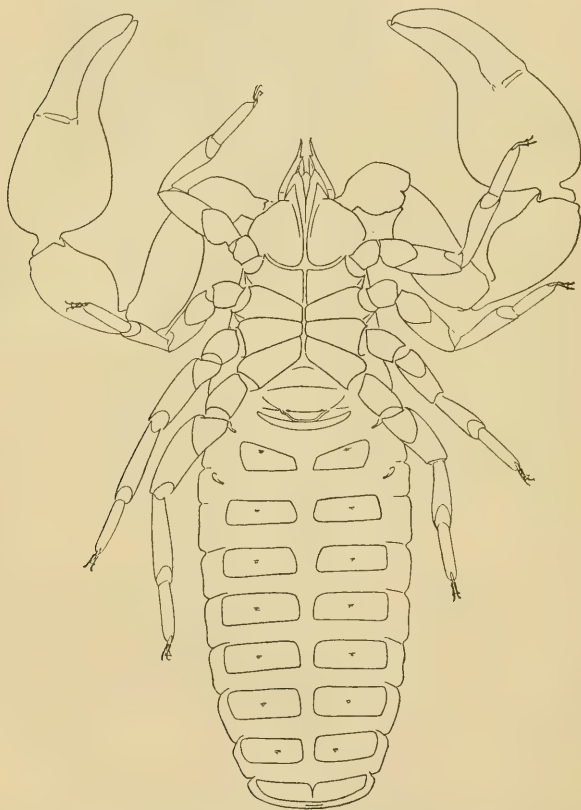
III. *Pairing of Chelifer cyrneus L. Koch.*

Chelifer cyrneus is known with us only in Sherwood Forest (Nottinghamshire) and Richmond Park (Surrey), where it lives under rather close-fitting bark of dead or partly dead oak-trees.

* The occurrence, in this Order, of a spermatophore, though not mentioned in the text-books, is not entirely new, since McIntire (5) saw *Chthonius* ♂, in captivity, extrude elongated structures in which were spermatozoa. No female appears to have been associated with the male during this act, and it is thus doubtful whether the extrusion was normal.

It belongs to the subgenus *Chernes*; and the male (text-fig. 48), in sharp contrast with that of *Chelifer latreillii*, is but little specialized. The genital area of this sex is only moderately conspicuous, the second genital plate being short; the fourth pair of coxæ differ only a little from those of the female, and there is no coxal sac; further, there are no protrusible ram's-horn organs, and the legs of the first pair exhibit no marked modification. A slight enlargement of the hands of the palp, in fact, is the only secondary character of note.

Text-fig. 48.



Chelifer cyrneus L. Koch.

Male in ventral view. $\times 20$.

(The bristles and tactile-hairs are omitted.)

Compared with *Chelifer latreillii*, the present animal is much larger and more heavily built, and unlike the former species, it is

eyeless. In the male, in addition to the important differences above indicated, there is a deep-seated unlikeness in the internal organs; and we shall find that the spermatophores are entirely unlike, with corresponding differences in the pairing.

In the second week of April 1911, a supply of specimens was obtained from Richmond Park*, and a cell was stocked with five or six individuals, which were kept under daily observation till the beginning of the second week of May. During this time, fortunately, abundant opportunities were afforded for observing the pairing, which was carried on with great persistence on at least eight occasions. The animals did not walk easily on the under surface of the glass, and pairing was not observed in that position; it was well seen, however, both in dorsal and lateral view, and under the latter condition the details of the process were distinctly made out.

The male and female met, as already stated, in walking position head to head (text-fig. 49, p. 384); and, as in the former species, they engaged in some preliminary fencing with the palps. During this fencing the male always obtained with one of the hands a firm grasp of one of the hands of the female; and, contrary to what occurred in the former species, this grasp was always maintained throughout, that is to say until the animals parted company when the pairing for the time being was complete. Moreover, while the former species held the female with both hands, the present animal invariably employed one hand only in this way, always keeping the other hand free. After the grasp was made, the animals fenced with the free palp and moved about a little backwards and forwards; the male—all the time alert and eager—constantly attempting to approach closely to the female. Watching the animals carefully at this time, it was soon observed that the fencing had given place to a regular system of display on the part of the male, whose actions in this respect were quite unlike anything seen in the former species. In the present case—in the absence of ram's-horn organs—the display was made with the free palp and with the legs of the first pair. The free palp was brought round at frequent intervals and the great hand rapidly shaken in the face of the female in a remarkable threatening or perhaps beckoning manner; and the first legs were rapidly moved, that is to say lifted and replaced, in most peculiar fashion. After a time the female, apparently much impressed with these actions, offered little or no resistance, the male having now no difficulty in approaching closely. At length the male—head to head with the female but not in contact except for the continuous grasp of one hand—deflected the base of the abdomen to the floor and affixed there the adhesive foot-like attachment of the spermatophore. Almost immediately, the body was raised to its normal position,

* The writer is indebted to His Majesty's Office of Works and to Mr. S. Pullman, the Superintendent of the Park, for the permission and facilities necessary for the taking of the animals in this place.

Text-fig. 49.

Pairing of *Chelifer cyrneus* L. Koch. $\times 10$.

A. Female confronted by male with completed spermatophore. B. Male retreating backwards, female coming forwards to the spermatophore. C. Female receiving the sperma.

(The appendages of the left side of the male and of the right side of the female, the bristles, and the tactile-hairs are omitted.)

and one then saw that a whitish filament was stretched from the foot-like attachment to the genital opening; and now the male produced very quickly from the genital opening a large globule of brilliant liquid; and this globule remained on the filament, just below the genital opening, like a great bead on a thread. Standing thus for some moments, perhaps awaiting some sign from the female, and continuing with great energy the shaking of the free hand, the male at last quickly raised his body and took a step or two backwards so as to free the globule and filament; and it was now seen that the filament, which passed through the globule, bore just above it a small irregular termination of whitish substance. The remarkable spermatophore thus completed remained standing on the ground in an erect or suberect position. At the moment when the male raised his body and stepped back, the female, still held by the hand by the male, ran forward; the movement of the two animals being perfectly mutual and just sufficient to bring the genital area of the female into the exact position occupied the moment before by that of the male. As the female thus ran forward the genital orifice was widely open; and just as the spermatophore was reached a slight forward and downward movement was made upon it; and, the genital orifice being quickly closed, the globule together with the whitish termination of the filament were taken in at a gulp. Only the naked filament remained. At the moment of this rapid gulping in, the female drew back; and at the same moment the male, with great eagerness and with the chelicere extended and open, ran forward until the fore parts of male and female were in contact; and the two animals remained thus in a state of quiescent embrace for some time. During this embrace the head of the male went under that of the female; but no part of the male was at any time directed towards the female genital opening. The coupling action of the legs of the first pair, which appears to be an essential condition in the pairing of *Chelifer latreillii*, had no counterpart in the present species. At the conclusion of this period of repose, the male roused himself to activity again, recommenced the rapid movements of the free palp and of the legs of the first pair, and the whole process was repeated.

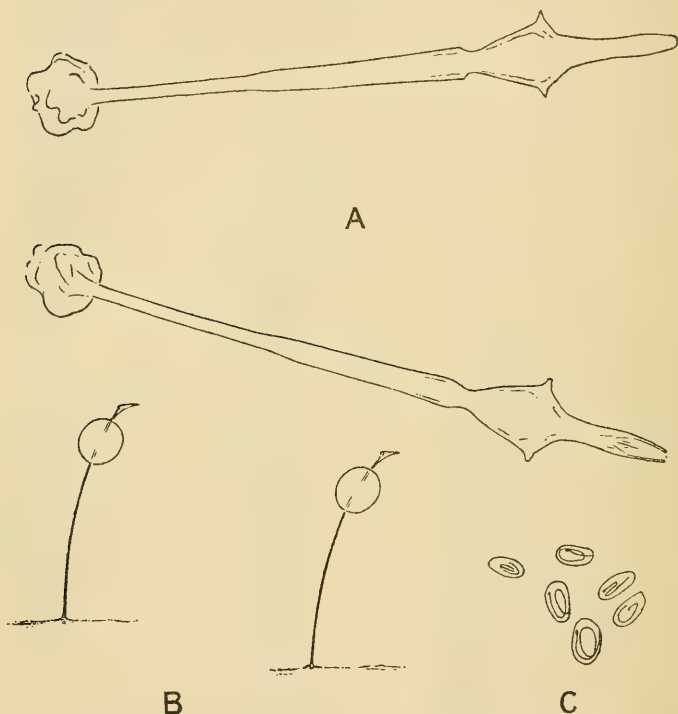
The whole process was, in fact, always repeated many times. To this there was no exception in all the observations. The male never once released, not even during the periods of repose, the fixed grasp of the hand of the female; spermatophores were regularly produced and received at intervals of from eight to ten minutes; and this recurrent pairing was continued for two hours, or even for three hours, or more.

By the beginning of the second week of May the activity of the males showed signs of abating, and the colony was broken up. Soon afterwards, however, a new colony was established, and pairing was seen again in July and August.

Text-fig. 50 B shows the spermatophore—two of them—in lateral view. This object agrees with that of the former species in its attachment to the floor, but is otherwise of different character,

being altogether more simple and smaller. Beyond the small foot of attachment it consists, as we have seen, merely of a simple, more or less rigid filament, which bears around it near the top a large globule of liquid and has just above the globule an irregular termination of whitish substance.

Text-fig. 50.



A. Spermatophore of *Chelifer latreillii* Leach, from above and from below. $\times 50$.

B. Spermatophores of *Chelifer cyrneus* L. Koch, from the side. $\times 50$.

C. Spermatozoa of *Chelifer cyrneus* L. Koch. (Drawing communicated to the writer by Mr. C. J. With.)

The globule has a diameter somewhat exceeding the depth of the tibia of the legs of the animals. Unfortunately it was not ascertained whether the spermatozoa (text-fig. 50C) were contained in the globule or above it at the termination of the filament—from my experience in this direction the obtaining of a complete spermatophore for examination will not be an easy task—but however this may be, the amount of material transferred from the male to the female is surprisingly large.

On the breaking up of the first colony, the animals were despatched to Mr. C. J. With of Copenhagen, who obligingly examined them, and found spermatozoa in the females. These formed a mass in the vagina; and occurred also, placed in a single row, in the two long narrow irregularly-coiled tubes which run out from the vagina anteriorly. These tubes were figured in an allied species by Croneberg (9). From their structure, and from the presence of spermatozoa which would evidently be preserved there, they must be regarded as receptacula seminis, not as glands as Croneberg supposed*.

It was on the present species that Schtschelkanowzeff (17) made the already published observations to which reference is made at the commencement of this paper†. He found the animal in the Russian Government of Tschernigoff, in a forest belonging to his father, where certain pine-stumps were reserved for the purposes of observation. By removing the bark from these stumps he was able to learn much of the animal's manner of life, and frequently saw their pairing. He relates that after the grasping of one hand and other preliminaries, the male made some convulsive movements and depressed the abdomen to the stump; and thereupon the female took the place of the male and depressed her abdomen exactly at the spot where the male had done so; and these actions were repeated several times. The male, he concluded, had deposited sperm and the female had taken it up; and on subsequent dissection of the female, spermatozoa were detected in the vagina and receptacula seminis. This impression of the pairing, it will be seen, is roughly in agreement with the account above given; it is, in fact, exactly what would be obtained by a not very close observation of the animals in dorsal view, in the open, with or without a lens. Presumably they were not viewed laterally, for the sperm was supposed to have been deposited in little heaps; and thus there is no mention of the characteristic spermatophore. Schtschelkanowzeff supposed, finally, that the active rôle was taken throughout by the female; but in this, doubtless, he was mistaken.

IV. Summary.

The two Pseudoscorpiones observed belong to the genus *Chelifer* s.l., and represent respectively the subgenera *Chelifer* s.s. and *Chernes*.

The males are differently equipped: the *Chelifer* has an elaborate genital area, long ram's-horn organs, and much modified legs of the first pair; the *Chernes* has a less elaborate genital area, no ram's-horn organs, and no modified legs. There is agreement,

* This result appears to have been arrived at already by Schtschelkanowzeff (17, p. 27), and cf. Lubbock (3, p. 615).

† Schtschelkanowzeff (11) described his animal as *C. multidentatus*, sp. n.; but paratypes obligingly communicated to the writer establish its identity with *C. cyrneus*.

however, in a feature of prime importance : both are destitute of intromittent organs of copulation.

Fertilization is effected in both by means of a spermatophore.

This structure in the *Chelifer* is large and somewhat complicated ; in the *Chernes* relatively small and merely filiform.

Correlated with the differences in equipment and in the spermatophore are considerable differences in the pairing.

There is agreement, however, as follows. The male and female face one another in walking position. The male grasps with one or both hands one or both hands of the female. There is a forced courtship, during which the male makes display of definite character. At length he extrudes the spermatophore, which is attached to the floor in front of the female, where it stands erect or obliquely. From this object the male retires backwards, and the female at the same moment comes forwards. The movement is just sufficient to bring the female genital opening into contact with the spermatophore, and the male product is thus received without delay.

The differences may thus be stated. The *Chelifer* male holds the female with both hands ; and makes display with the ram's-horn organs. He releases the hands previously to the extrusion of the spermatophore. When the female comes forward, he seizes her by the genital opening with the legs of the first pair, and then executes a series of pulling movements by which presumably the reception of the male product is facilitated. The animals now separate ; and it is unlikely that the process is repeated, except perhaps at long intervals. The *Chernes* male holds the female with one hand only. He makes his display with the other hand and with the legs of the first pair. He does not release the female previously to the extrusion of the spermatophore, but continues to hold her by the hand throughout. When the female reaches the spermatophore, she takes the male product quickly and retires backwards. There is no seizing of the genital opening by the male. As the female retires, however, the male quickly follows ; and there is a period of repose ; after which the whole process is repeated. Moreover, it is repeated, with similar periods of repose, many times ; and a large number of spermatophores are thus produced and received in rather quick succession.

By way of conclusion it may be recalled that the genus *Chelifer* s.l. comprises, in addition to the subgenera *Chelifer* s.s. and *Chernes*, two others, *Atemnus* and *Withius* : all distinguished by remarkable differences in the sexual equipment of the males—even within the subgenera there are striking divergences in the secondary characters ; and these facts, in view of the differences above noted, certainly lead one to expect great variations in the pairing processes. A review of the males of the whole Order, moreover, serves greatly to increase this expectation—one may refer for instance to the complete dissimilarity in the genital areas of *Obisium* and *Cithonius*—so that there is here undoubtedly

a fertile field for investigation. Nevertheless it may perhaps be predicted that the general lines now indicated are those on which fertilization will be found to be effected in all Pseudoscorpiones.

V. List of References.

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EXHIBITIONS AND NOTICES.

February 20, 1912.

Dr. A. SMITH WOODWARD, F.R.S., Vice-President,
in the Chair.

Dr. A. T. MASTERMAN, M.A., F.Z.S., gave a demonstration, illustrated by a large number of lantern-slides, of recent investigations on Age-determination in the Scales of Salmonoids, with special reference to Wye Salmon.

March 5, 1912.

SIR JOHN ROSE BRADFORD, M.D., D.Sc., F.R.S.,
Vice-President, in the Chair.

The Races of the European Wild Swine *.

Mr. OLDFIELD THOMAS, F.R.S., F.Z.S., exhibited the skull of a Hungarian Wild Boar, recently presented to the National Museum by Fräulein Sarolta von Wertheimstein, and that of an ordinary German Wild Boar, representing the typical *Sus scrofa* Linn.

* [The complete account of the new forms described in this paper is given here, but since the names and preliminary diagnoses were published in the 'Abstract,' they are distinguished by being underlined.—EDITOR.]

The difference in size between these two skulls was so enormous that Mr. Thomas expressed the opinion that the Hungarian Boar should be distinguished as a different species, which he proposed to call *Sus attila*. A fine stuffed specimen of the same species, from Volhynia, S. Russia, presented by Count Potocki, had been on exhibition for some years in the Museum, under the old name of *Sus scrofa*.

The difference between the two species was mainly in size, as would appear from the skull-measurements given below; but it might be noticed that both specimens of *Sus attila* were, on the whole, lighter in colour, and had whiter muzzles, than the available specimens of *Sus scrofa*. No series of skins, however, was available to show how far these colour-differences were constant. The character of the pelage of *Sus attila* was similar to that of *S. scrofa* in the presence of a thick woolly underfur. The median anterior hoofs in *Sus attila* were 65 mm. in length, as compared with 48 mm. in *S. scrofa*.

The type locality of *S. attila* was Kolozsvár (=Klausenburg), Transylvania, and the species no doubt extended through Russia into Siberia.

The other names usually placed in the synonymy of *Sus scrofa*—*setosus* Boddaert, *aper* Boddaert, *europæus* Pallas, and *celtica* Strobel—were all merely suggested alternatives for *scrofa*, and applied solely to the German Wild Boar, this being the typical form of Linnaeus's species*.

Furthermore, Mr. Thomas pointed out that the Wild Boar of Southern Spain was, on the other hand, so very much smaller than the true *Sus scrofa* of Germany that it appeared worthy of a special subspecific name, and he proposed to call it *Sus scrofa baticus*. In addition to its small size, the two skins in the British Museum (both of winter specimens) were remarkable for having no woolly underfur whatever, that of *Sus scrofa scrofa* being thick and abundant.

A female specimen of this small Wild Boar, from Seville, had been presented to the Museum by the late Lord Lilford in 1895, and a male skin and skull, and a separate skull, from the Coto Doñana, by Mr. Abel Chapman in 1908.

Finally, the Wild Boar of Northern Spain was intermediate in size between *S. s. baticus* and *S. s. scrofa*, and possessed, at least in winter, a woolly underfur as in ordinary Wild Boars. Of this form a fine male and female had been obtained for the Museum by the Rev. Saturio Gonzalez at Quintanar de la Sierra near Burgos.

Mr. Thomas proposed to call this race, whose skull-measurements were included in the table below, *Sus scrofa castilianus*.

The following were the skull-dimensions in millimetres of (1) the type of *S. attila*, an adult but not old male, (2) of a rather

* Cf. Thomas, P. Z. S. 1911, p. 110.

older male of *Sus scrofa* from Baden, Germany, (3) of the type skull of *S. s. castilianus*, and (4) that of *S. s. baeticus*, intermediate in age between the first two :—

	<i>Sus attila</i> .	<i>Sus scrofa</i> <i>scrofa</i> .	<i>Sus scrofa</i> <i>castilianus</i> *.	<i>Sus scrofa</i> <i>baeticus</i> .
	♂.	♂.	♂.	♂.
Occipito-nasal length	452	385	353	324
Condyllo-basal length	407	(c.) 355	335	(c.) 305
Zygomatic breadth	174	146	135	142
Interorbital breadth	102	79	78	72
Nasals, length	250	208	189	173
„ breadth	53	36	30	33
Median occipital height	159	...	114	...
„ „ „ skull on				
lower jaw	271	208	198	208
Height at anteorbital foramen ...	84	65	60	61
Upper cheek-tooth series	134	121	125	117
Lower molar series	84	69	79	72
Breadth of antero-internal face of				
lower canine	25.5	21.5	23	20
M ³	40×23.5	35×21	43×22	35.5×21
M ₃	41×19	36×17	42×17.5	36 ×17

The results arrived at were as follows :—

1. *SUS SCROFA* Linn.

Upper length of skull not exceeding about 410 mm.; height, including lower jaw, at most 210 mm.

Subspecies :—

1 A. *SUS SCROFA SCROFA*.

Synn. *setosus*, *aper*, *europæus*, *celtica*.

Upper length of skull of male about 380–410 mm. Woolly underfur present.

Range. Central Europe, from Germany to the Pyrenees.

Type locality. Germany.

1 B. *SUS SCROFA CASTILIANUS*.

Thos. Abstract P. Z. S. 1912, p. 13 (March 12).

Upper length of skull of male 353 mm., of female 331. Underfur present.

Range. Northern Spain.

Type locality. Quintanar de la Sierra, near Burgos.

Type. Adult male. B.M. No. 11.10.5.3. Collected by Rev. Saturio Gonzalez; presented by the Hon. N. Charles Rothschild.

* An old female skull of *S. s. castilianus* measured 331 mm. in occipito-nasal length.

1 c. SUS SCROFA BÆTICUS.

Thos. Abstract P. Z. S. 1912, p. 14 (March 12).

Upper length of skull of male 324 mm. No woolly underfur present, even in winter.

Range. Southern Spain.

Type locality. Coto Doñana, Huelva.

Type. Old male. B.M. No. 8.3.8.12. Collected 6 February, 1908, and presented by Abel Chapman, Esq.

2. SUS ATILA.

Thos. Abstract P. Z. S. 1912, p. 13 (March 12).

Upper length of skull of male 452 mm.; height, including lower jaw, 271 mm. Woolly underfur present.

Range. Hungary and S. Russia, probably extending into Siberia.

Type locality. Kolozsvár (= Klausenburg), Transylvania.

Type. Adult male. B.M. No. 12.1.23.1. Collected 8th December, 1911. Presented by Fräulein Sarolta von Wertheimstein.

PAPERS.

21. A Contribution towards the Knowledge of the Spiders and other Arachnids of Switzerland. By the Rev. O. PICKARD-CAMBRIDGE, M.A., F.R.S., C.M.Z.S., etc.

[Received October 13, 1911: Read February 20, 1912.]

(Text-figures 51 & 52.)

The materials for the accompanying List have been kindly got together for me by those whose initials are appended to each species. They have been collected for the most part during tours through Switzerland, and in one or two cases during short sojourns in some of the localities mentioned. It is not pretended that the number of species enumerated represents more than a small proportion* of those recorded by other authors, or likely to be found by careful expert search in Swiss regions, but it shows how very many objects in one special branch of Natural History can be obtained even by observers who may be non-specialists, as was the case with nearly all those whose initials are here appended. Of course it must be taken into consideration that in the collecting of Arachnids there is no necessity for the paraphernalia absolutely required for the collecting and preserving of entomological specimens in general. A few small bottles of methylated

* The present known number of Swiss Spiders, according to Dr. Roger de Lessert, amounts to 616. See *Revue Suisse Zool.* vol. xvii. p. 485, 1909.

spirit of wine, a few glass tubes of different sizes, contained in strong conveniently shaped tin boxes, are really all the materials that are needed for the preservation of Arachnids; while the "eye of faith and the finger of instinct" assisted by an empty glass tube will suffice in the actual field. Not, of course, but that a strong entomological sweeping hoop-net, for the brushing and sweeping of shrubs and herbage, would fill the pocket-bottles all the faster, and probably with some species not obtainable by other methods. The preponderance in the following List of those groups of Spiders which at once and most obviously claim the attention of the tourist as he toils along—viz., the Epeiridæ, Thomisidæ, Lycosidæ, and Salticidæ—shows, it seems to me, how rich a harvest would be reaped by a resident specialist in some of the localities. The number of species here recorded, in these four groups alone, amounts to 102 out of the total of 212 species collected of the Araneidea (or true Spiders); while those of the great group Theridiidæ (in its widest sense) are only 65 in number: a group which, I may remark in passing, numbers in the British Islands alone upwards of 250 out of a total of the whole Order of somewhere about 550! The greater number, however, of the Theridiidæ require something more in the way of wearisome search than even the most observant eye of the ordinary passing tourist; and hence the tourist's bottle is most commonly filled by species of the other four groups mentioned, and which, often in countless numbers, are obvious on all sides on a fine day in the mountains.

I must here acknowledge my indebtedness to Mons. Eugène Simon of Paris, and Dr. Roger de Lessert, of the Natural History Museum, Geneva, for their invaluable assistance in the identification of many of the species in the following List with which I was unacquainted.

LIST OF SWISS ARACHNIDS.

Collected, or sent to me, at various periods and in various localities by the following:—

Initials in List.

- A. W. P.-C. (A. W. Pickard-Cambridge, Balliol College, Oxford.)
- R. J. P.-C. (Rev. R. J. Pickard-Cambridge, Warmwell Rectory, Dorchester.)
- H. A. P. (late Rev. H. A. Pickard, Airedale, Oxford.)
- C. W. (Cecil Warburton, Christ's College, Cambridge.)
- F. P. S. (F. P. Smith, 5 Gibson Square, London.)
- R. G. (Robert Godfrey, late of 46 Cumberland Street, Edinburgh.)
- G. N. (late George Nicholson, Director, Royal Gardens, Kew, and 37 Larkfield Road, Richmond.)
- A. S. A. (late A. S. Atkinson, Nelson, New Zealand.)

Initials in List.

- E. S. (Eugène Simon, 16 Villa Säid, Avenue du bois de Boulogne, Paris.)
 A. E. E. (Rev. A. E. Eaton, Symondsburys, Bridport, Dorset.)
 H. S. (Henry Speyer, Reigate.)
 R. de L. (Dr. Roger de Lessert, Museum of Natural History, Geneva.)
 C. E. M. I. (C. E. M. Ince, per late F. O. Pickard-Cambridge.)
 C. (Dr. Collingwood, the late.)

Class ARACHNIDA.

Order ARANEIDEA.

Fam. DYSDERIDÆ.

- Harpactes drassoides* Sim. Chamounix. R. J. P.-C.
Segestria senoculata Linn. Simplon. A. S. A.

Fam. DRASSIDÆ.

- Drassus hispanus* L. Koch. Suldén-Tyrol. A. W. P.-C.
 „ *troglydites* C. L. Koch. Zinal, Engstlen Alp, and Châlet de Melèze, St. Gervais les Bains. A. W. P.-C. Simplon. A. S. A. Zermatt. R. J. P.-C. Switzerland. G. N.
Drassodes lapidosus Walek. Simplon. A. S. A. Switzerland. H. S. Chamounix. R. J. P.-C. St. Gervais les Bains. A. W. P.-C. Montreux. C.
 „ *pubescens* Thor. Arolla. A. W. P.-C.
Prosthesima apricorum L. Koch. Simplon. A. S. A.
 „ *talpina* L. Koch. Bel Alp. G. N.
 „ *petiverii* Scop. Montreux. C.
 „ *nigrita* Fabr. Châlet de Melèze, St. Gervais les Bains. A. W. P.-C.
 „ *latreillii* Sim. St. Gervais les Bains. A. W. P.-C.
 „ *præfica* L. Koch. "Switzerland." H. S.
Callilepis nocturna Linn. St. Gervais les Bains. A. W. P.-C. Simplon. A. S. A. Switzerland. H. S.
Gnaphosa badia L. Koch. (*G. molesta* Cambr.) St. Gervais les Bains, Arolla, and Suldén-Tyrol. A. W. P.-C.
 „ *petrobia* L. Koch. Switzerland. G. N. and R. J. P.-C.
 „ *tigrina* Sim. Switzerland. R. J. P.-C.
Micaria hospes Kulcz. Simplon. A. S. A.
 „ *breviuscula* Sim. Zermatt. R. J. P.-C.
 „ *scenica* Sim. Bel Alp. G. N. Zermatt. R. J. P.-C. Zinal. A. W. P.-C.
 „ *pulicaria* Sund. St. Gervais les Bains. A. W. P.-C.

- Clubiona hilaris* Sim. Simplon. A. S. A.
Cheiracanthium italicum Can. & Pav. Zermatt. H. S.
Zora maculata Bl. Chamounix. A. W. P.-C. Montreux. C.

Fam. DICTYNIDÆ.

- Dictyna viridissima* Walck. Alps. E. S.
 „ *flavescens* Walck. Alps. E. S.
 „ *uncinata* Westr. Switzerland. H. S.
Amaurobius fenestralis Stroem. Simplon. A. S. A. Zinal.
 A. W. P.-C. Montreux. C.
 „ *ferox* Walck. Montreux. C.
 „ *4-guttatus* Hahn. Alps. E. S.

Fam. AGELENIDÆ.

- Cryphæa silvicola* C. L. Koch. Zinal. A. W. P.-C.
Celotes terrestris Wid. Switzerland. R. G. and A. W. P. C.
 Interlaken. A. E. E.
 „ *pickardii* Cambr. Switzerland. H. A. P.
 „ *atropos* Walck. Chamounix. A. W. P.-C. Switzerland.
 H. S.
 „ *claustrarius* Hahn. Switzerland. R. G., A. E. E.,
 R. J. P.-C., and G. N.
Tegenaria campestris C. L. Koch. Alps. E. S.
 „ *tridentina* L. Koch. Simplon. A. S. A.
 „ *derhamii* Scop. Montreux. C.
 „ *pusilla* Sim. Chamounix. A. W. P.-C.
 „ *domestica* Clk. Montreux. C.
Cicurina cinerea Panz. Switzerland. R. G.
Textrix denticulata Oliv. Simplon. A. S. A. Bel Alp. G. N.
 Montreux. C.
Agelena labyrinthica Clk. Simplon. A. S. A. Switzerland. H. S.,
 R. J. P.-C., and H. A. P. Montreux. C.

Fam. ZODARIIDÆ.

- Zodarion gallicum* Sim. Alps. E. S.

Fam. PHOLCIDÆ.

- Pholcus phalangioides* Fuess. Montreux. C.

Fam. THERIDIIDÆ.

- Episinus truncatus* Walck. Montreux. C.
Theridion riparium Bl. Switzerland. R. G.
 „ *bigibbum*, sp. n. (text-fig. 51). Alps. E. S. (For
 description see appendix, p. 403.)

- Theridion sisypium* Clk. Simplon. A. S. A. Zinal and Engstlen
Alp. A. W. P.-C. Switzerland. H. S.
and H. A. P. Montreux. C.
- „ *nigro-variegatum* Sim. Geneva. R. de L.
- „ *nigro-punctatum* Luc. Alps. E. S.
- „ *blackwallii* Cambr. Alps. E. S.
- Phyllonethis lineata* Clk. Switzerland. H. A. P.
- Dipæna braccata* C. L. Koch. Alps. E. S.
- Steatoda bipunctata* Linn. Simplon. A. S. A.
- Lithyphantes corollatus* Linn. Alps. E. S.
- „ *paykullianus* Clk. Alps. E. S.
- Teutana grossa* C. L. Koch. Alps. E. S.
- Euryopis flavomaculata* C. L. Koch. Alps. E. S.
- Asagena phalerata* Panz. Alps. E. S. Switzerland. G. N.
Chamounix. A. W. P.-C.
- Enoplognatha thoracica* Wid. Alps. E. S.
- Robertus lividus* Bl. Simplon. A. S. A. Arolla. A. W. P.-C.
- Tapinopa longidens* Wid. Alps. E. S.
- Bolyphantes alticeps* Sund. St. Gervais les Bains. A. W. P.-C.
- Drapetisca socialis* Sund. Switzerland. C. E. M. I.
- Linyphia marginata* C. L. Koch. Switzerland. G. N.
- „ *triangularis* Clk. Alps. E. S. Montreux. C.
- „ *phrygiana* C. L. Koch. Alps. E. S.
- „ *montana* Clk. Simplon. A. S. A. Switzerland. H. A. P.
- „ *pusilla* Sund. St. Gervais les Bains. A. W. P.-C.
- „ *frutetorum* C. L. Koch. Alps. E. S.
- „ *emphana* Walck. Alps. E. S.
- „ *hortensis* Sund. Alps. E. S.
- Leptyphantes tenuis* Bl. St. Gervais les Bains. A. W. P.-C.
- „ *fragilis* Thos. Zinal. A. W. P.-C.
- „ *expuncta* Cambr. Zinal. A. W. P.-C.
- „ *tenebricola* Wid. Switzerland. G. N. Alps. E. S.
Sulden-Tyrol. A. W. P.-C.
- „ *pulcher* Kulcz. Simplon. A. S. A. Sulden-Tyrol.
A. W. P.-C.
- „ *mengii* Kulez. Arolla. A. W. P.-C.
- „ *minutus* Bl. Chrissons. R. J. P.-C.
- „ *leprosus* Ohl. Montreux. C.
- Bathyphantes concolor* Wid. Gorge of Massa. G. N. Chamounix.
R. J. P.-C.
- „ *variegatus* Bl. Switzerland. G. N.
- Hilaira montigena* L. Koch. Eggishorn. G. N.
- Tigellinus saxicola* Camb. Geneva. R. de L.
- Triconchus mæbi* Dahl-Bös. Chamounix. A. W. P.-C.
- Centromerus subalpinus* Lessert. Geneva. R. de L.
- „ *afinis* Wid. (= *C. pabulator* Cambr.-Less.). Engstlen
Alp, or St. Gervais les Bains. A. W. P.-C.
- Micryphantes gulosa* L. Koch. Eggishorn. A. W. P.-C.
- Oreoneta fortunata* Cambr. St. Gervais les Bains. A. W. P.-C.

- Microneta rurestris* C. L. Koch. Eggishorn and St. Gervais les Bains. A. W. P.-C.
- „ *viaria* Bl. Arolla. A. W. P.-C.
- Gongylidium apicatum* Bl. Bel Alp. G. N.
- Erigone tirolensis* L. Koch. Switzerland. G. N. Bel Alp. G. N.
- „ *remota* L. Koch. Bel Alp. G. N.
- „ *atra* Bl. Alps. E. S.
- „ *jugorum* L. Koch.
- „ *dentipalpis* Wid. St. Gervais les Bains. A. W. P.-C.
- Diplocephalus cristatus* Bl. St. Gervais les Bains. A. W. P.-C. Chamounix. R. J. P.-C.
- „ *castaneipes* Sim.-Lessert. Geneva. R. de L.
- „ *kochii* Lebert-Lessert. Geneva. R. de L.
- „ *eborodunensis* Cambr. Engstlen Alp. A. W. P.-C.
- Lophocarenum nemorale* Bl. Geneva. R. de L. (Sent to me as *L. stramineum* Menge.)
- Nematogmus sanguinolentus* Walck. Alps. E. S.
- Araconcus altissimus* Sim. Bel Alp. G. N.
- Styloctetor* (sub *Hilaira*) *carli* Lessert (sent to me for examination by Lessert). Geneva. R. de L. (Appears to me to be rather a *Styloctetor* than a *Hilaira*.)
- „ *broccha* L. Koch. Geneva. R. de L.
- Tapinocyba affinis* Lessert. Geneva. R. de L.
- „ *pallens* Cambr. Geneva. R. de L.
- Ceratinella brevis* Wid. St. Gervais les Bains. A. W. P.-C.

Fam. ULOBORIDÆ.

- Hyptiotes paradoxus* C. L. Koch. Simplon. A. S. A.

Fam. EPEIRIDÆ.

Subfam. TETRAGNATHINÆ.

- Tetragnatha extensa* Linn. Switzerland. H. S. Montreux. C.
- Pachygnatha degeerii* Sund. Switzerland. C. E. M. I.
- Meta merianæ* Scop. Simplon. A. S. A. Switzerland. G. N. Montreux. C.
- „ *menardi* Latr. Montreux. C.
- „ *segmentata* Clk. Simplon. A. S. A. St. Gervais les Bains. A. W. P.-C. Switzerland. R. G. Montreux. C.

Subfam. ARGIOPINÆ.

- Cyclosa conica* Pall. Simplon. A. S. A.

Subfam. EPEIRINÆ.

- Zilla montana* C. L. Koch. Switzerland. G. N. Simplon. A. S. A. Alps. E. S.
- „ *x-notata* Clk. Montreux. C.

- Zilla stroemii* Thor. Switzerland. G. N.
Cercidia prominens Westr. Alps. E. S.
Singa albobittata Westr. Switzerland. G. N.
 „ *hamata* Clk. Alps. E. S.
Epeira nordmannii Thor. Zinal. A. W. P.-C.
 „ *carbonaria* L. Koch. Switzerland. G. N.
 „ *alpica* L. Koch. Switzerland. G. N.
 „ *circe* Sav. Simplon. A. S. A.
 „ *cucurbitina* Clk. Simplon. A. S. A. Switzerland. H. A. P.
 Montreux. C.
 „ *diademata* Clk. Switzerland. H. S., R. G., R. J. P.-C.,
 G. N., and H. A. P. Simplon. A. S. A.
 Montreux. C.
 „ *ceropegia* Walek. Simplon. A. S. A. Switzerland. G. N.
 St. Gervais les Bains. A. W. P.-C.
 Halkern Thal. A. E. E. Zernatt.
 R. J. P.-C.
 „ *pyramidata* Clk. Halkern Thal. A. E. E. Switzerland.
 H. A. P.
 „ *marmorea* Clk. St. Gervais les Bains. A. W. P.-C.
 Switzerland. H. A. P.
 „ *sclopetaria* Clk. Montreux. C.
 „ *quadrata* Clk. St. Gervais les Bains. A. W. P.-C.
 „ *dioidea* Walek. Montreux. C.
 „ *adianta* Walek. Alps. E. S.
 „ *triguttata* Fabr. Geneva. R. de L.
 „ *sturmii* Hahn (*agalea* Bl.). Geneva. R. de L.
 „ *redii* Scop. Montreux. C.
 „ *montana* C. L. Koch. Alps. E. S.

Fam. THOMISIDÆ.

- Thomisus onustus* Walek. Montreux. C.
Misumena vatia Clk. Simplon. A. S. A.
Dicea dorsata Fabr. Montreux. C.
Xysticus cristatus Clk. Switzerland. R. G. Simplon. A. S. A.
 St. Gervais les Bains. A. W. P.-C.
 Montreux. C.
 „ *lanio* C. L. Koch. Switzerland. R. G.
 „ *gallicus* Sim. St. Gervais les Bains, Arolla, and
 Eggishorn. A. W. P.-C.
 „ *kochii* Thor. Switzerland. R. J. P.-C.
 „ *pini* C. L. Koch. Simplon. A. S. A. Montreux. C.
 „ *lateralis* Hahn. Switzerland. R. G.
 „ *glacialis* L. Koch. Gorge of Massa and Bel Alp. G. N.
 „ *luctator* L. Koch. Simplon. A. S. A.
 „ *bifasciatus* C. L. Koch. Switzerland. R. J. P.-C.
 „ *erraticus* Bl. Arolla. A. W. P.-C.

- Philodromus alpestris* C. L. Koch. Simplon. A. S. A. Zermatt.
R. J. P.-C. Arolla and St. Gervais
les Bains. A. W. P.-C. Switzer-
land. G. N.
- „ *lividus* Simon. Switzerland. G. N.
- „ *laricium* Simon. Switzerland. G. N.
- „ *collinus* C. L. Koch. Switzerland. C. W.
- „ *margaritatus* Clk. Simplon. A. S. A. Switzerland.
G. N. Var.: *jejunus* Panz. Switzer-
land. C. E. M. I.
- „ *emarginatus* Schr. Simplon. A. S. A.
- Thanatus arenarius* Thor. Eggishorn. A. W. P.-C.
- „ *formicinus* Clk. Simplon. A. S. A. Montreux. C.
Eggishorn and Suldén-Tyrol.
A. W. P.-C. Switzerland. G. N.

Fam. SPARASSIDÆ

- Micrommata virescens* Clk. Switzerland. R. G. Simplon. A. S. A.
Montreux. C.

Fam. PISAURIDÆ.

- Pisaura mirabilis* Clk. Switzerland. R. J. P.-C. and H. A. P.
Montreux. C.

Fam. LYCOSIDÆ.

- Dolomedes fimbriatus* Walck. Halkern Thal. A. E. E.
- Trochosa terricola* Thor. Chamounix. R. J. P.-C. Switzerland.
H. A. P.
- „ *leopardus* Sund. St. Gervais les Bains. A. W. P.-C.
Switzerland. H. A. P.
- Pirata latitans* Bl. St. Gervais les Bains. A. W. P.-C. Montreux. C.
- Tarentula andrenivora* Walck. Arolla. A. W. P.-C. Switzerland.
G. N. Montreux. C.
- „ *lessertii*, sp. n. (text-fig. 52). Switzerland. H. S. (For
description see appendix, p. 404.)
- „ *pulverulenta* Clk. Arolla and St. Gervais les Bains.
A. W. P.-C. Simplon. A. S. A.
Zermatt. R. J. P.-C. Switzerland.
G. N. and H. A. P.
- „ *trabalis* Clk. Simplon. A. S. A. Switzerland. G. N.
Zermatt. R. J. P.-C.
- „ *miniata* C. L. Koch. Montreux. C.
- „ *nemoralis* Westr. Gorge of Massa and Bel Alp. G. N.
St. Gervais les Bains. A. W. P.-C.
Simplon. A. S. A.
- „ *barbipes* Sund. Gorge of Massa. G. N.

- Tarentula aculeata* Clk.-Lessert (= *T. accentuata* auctt., Lessert).
Zermatt and Schiedeger. R. J. P.-C. Arolla.
A. W. P.-C.
- Lycosa amentata* Clk. Switzerland. R. J. P.-C., G. N., and H. A. P.
Simplon. A. S. A. Engstlen Alp and
St. Gervais les Bains. A. W. P.-C.
- „ *paludicola* Clk. Switzerland. C. W.
- „ *accentuata* Walek.-Sim. Switzerland. F. P. S.
- „ *pulverulenta* Clk.-Sim. Switzerland. F. P. S. St. Gervais
les Bains. A. W. P.-C.
- „ *nigra* C. L. Koch. Zermatt and Zinal. A. W. P.-C. Switz-
erland. G. N. and R. G. Zermatt.
R. J. P.-C.
- „ *blanda* C. L. Koch (& *cursoria*, auctt.). Sulden-Tyrol,
St. Gervais les Bains, Zinal, Cha-
mounix, and Arolla. A. W. P.-C.
Switzerland, Gorge of Massa, and
Bel Alp. G. N. Simplon. A. S. A.
Chamounix and Zermatt. R. J. P.-C.
- „ *giebeli* Pav. Switzerland and Zermatt. R. J. P.-C. Zinal.
A. W. P.-C. Switzerland, Bel Alp. G. N.
- „ *riparia* C. L. Koch. Switzerland. G. N. Zermatt.
R. J. P.-C. St. Gervais les Bains
and Switzerland. A. W. P.-C.
- „ *ferruginea* L. Koch. Zermatt and Sulden-Tyrol. A. W. P.-C.
- „ *bifasciata* C. L. Koch. Montreux. C.
- „ *pedestris* Sim. Switzerland. R. J. P.-C.
- „ *monticola* C. L. Koch. Aletsch Glacier, Zinal, and Switzer-
land. A. W. P.-C. Bel Alp and
Switzerland. G. N. Eggishorn.
A. W. P.-C.
- „ *lugubris* Walek. Rhone Glacier. R. J. P.-C. Switzerland.
G. N.
- „ *torrentum* Sim. Bel Alp and Switzerland. G. N.
- „ *wagleri* Hahn. Switzerland, Rhone Glacier, and Zermatt.
R. J. P.-C.
- „ *palustris* Linn. Switzerland and St. Gervais les Bains.
A. W. P.-C.
- „ *ludovica* Dahl. Simplon. A. S. A. Engstlen Alp. A. W.
P.-C.
- „ *mixta* Kulcz. Simplon. A. S. A. Gorge of Massa. G. N.
- „ *tarsalis* Thor. Simplon. A. S. A. St. Gervais les Bains
and Chamounix. A. W. P.-C.
- „ *albata* L. Koch. Bel Alp. G. N. Switzerland. R. J. P.-C.
St. Gervais les Bains. A. W. P.-C.
- „ *agrestis* Westr. Switzerland. H. S.
- Aulonia albimana* Walek. Montreux. C.

Fam. SALTICIDÆ.

- Epiblemum scenicum* Clk. Simplon. A. S. A. Bel Alp. G. N. Arolla and St. Gervais les Bains. A. W. P.-C. Montreux. C.
- Heliophanus metallicus* Sim. Arolla and Eggishorn. A. W. P.-C.
- „ *æneus* Hahn. Switzerland. G. N. Simplon. A. S. A. Montreux. C. Arolla. A. W. P.-C. Zermatt. R. J. P.-C.
- Euophrys petrensis* C. L. Koch. Arolla and Eggishorn. A. W. P.-C. Switzerland. G. N.
- „ *pictilis* Sim. St. Gervais les Bains. A. W. P.-C.
- „ *frontalis* Walck. Chamounix. A. W. P.-C.
- „ *erratica* Walck. Switzerland. R. G.
- Sitticus longipes* Can. Simplon. A. S. A.
- Attulus histrio* Sim. Simplon. A. S. A.
- Attus rupicola* C. L. Koch. Rhone Glacier and Switzerland. R. J. P.-C. and H. A. P.
- „ *pubescens* C. L. Koch. Switzerland. G. N.
- Dendryphantes encarpatus* Walck. Montreux. C.
- Philæus chrysops* Poda. Simplon. A. S. A.
- Ælurops v-insignitus* Clk. Eggishorn and Arolla. A. W. P.-C. Simplon. A. S. A.
- Pellenes lapponicus* Sund. Chamounix. R. J. P.-C.
- Synageles venator* Luc. Chamounix. A. W. P.-C.

Order PHALANGIDEA.

- Homalenotus quadridentatus* Cuv. Switzerland. C. W.
- Phalangium opilio* Linn. Switzerland. R. J. P.-C. Simplon. A. S. A. Switzerland. H. A. P.
- „ *parietinum* De Geer. Switzerland. H. A. P.
- „ *brevicorne* C. L. Koch. Zermatt. R. J. P.-C.
- Liobunum limbatum* L. Koch. Switzerland.
- „ *rotundum* Latr. Switzerland. R. J. P.-C.
- Platybunus pinetorum* C. L. Koch. Chamounix. R. J. P.-C.
- „ *triangularis* Herbst. Chamounix. A. W. P.-C.
- Oligolophus morio* Fabr.
- Var. *palliata* C. L. Koch. Eggishorn and St. Gervais les Bains. A. W. P.-C.
- Var. *glacialis* C. L. Koch. Bel Alp and Zermatt. R. J. P.-C.
- Var. *alpinus* Herbst. Simplon. A. S. A. Zinal, Arolla, St. Gervais les Bains, Chamounix, and Suldental. A. W. P.-C. Chamounix. R. J. P.-C. Bel Alp. G. N.
- Normal form. St. Gervais les Bains. A. W. P.-C. Switzerland. R. J. P.-C. and G. N.
- Megabunus rhinoceros* Can. Simplon. A. S. A. Switzerland. G. N.

Nemastoma dentipalpe Auss. Chamounix. A. W. P.-C.
 „ *quadripunctatum* Perty. Interlaken. R. G.

Order **CHERNETIDEA.**

(Pseudo-scorpiones.)

Obisium jugorum L. Koch. Zermatt. R. J. P.-C.
Chthonius tetrachelatus Preyssl. Interlaken. R. G.

Order **ACARIDEA.**

Cæculus echinipes L. Dufour. Zermatt. R. J. P.-C.

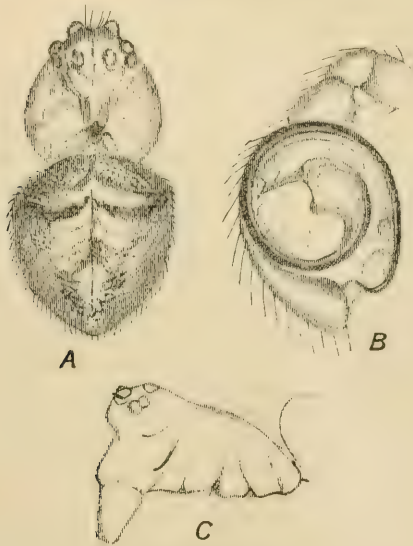
APPENDIX.

Description of *Theridion bigibbum*, sp. n. (Text-fig. 51.)

Adult male. Length $\frac{1}{11}$ of an inch or 1·7 mm.

The *cephalothorax* is broad, rounded behind. Caput prominent.

Text-fig. 51.



Theridion bigibbum.

- A. Cephalothorax and abdomen from above and behind.
 (Nat. length $\frac{1}{11}$ of an inch or 1·7 mm.)
- B. Left palpus (outer side).
- C. Cephalothorax (in profile).

Clypeus high. Colour dull yellow, a wedge-shaped dark blackish central band runs from, and includes, the ocular area to the

central impressions. The sides of the thorax are slightly margined also with blackish.

The *eyes* are rather large, and occupy the whole of the fore part of the caput. The four centrals form a large quadrangle rather longer than broad and a little narrower behind. The convexity of the curve of the hinder row is slightly directed backwards, and the interval between the hind-central pair of eyes is rather greater than that between each and the lateral eye next to it.

The *legs* (1, 4, 2, 3) are moderate in length and strength, of a pale yellowish-white hue, with a slight appearance of a dark but defective annulation at the extremities of the joints. They are furnished with hairs and a few slender bristles only.

The *palpi* are short, similar to the legs in colour. The digital joint very large, of an oval form; and the palpal organs, directed outwards, are simple in form but completely encircled on the margin by a long coiled black spine issuing from near the hinder margin, from and in connection with a largish corneous process, and ending in a fine somewhat sinuous slender point underneath the fore extremity of the joint.

Falces rather small and weak, and directed slightly forwards.

Maxillæ, *labium*, and *sternum* normal, and, with the falces, similar in colour to the cephalothorax.

The *abdomen* is large and of a general cretaceous white colour. Its form (looked at from above) is somewhat subtriangular, and at the shoulders (or each anterior fore corner) is a slight prominent point or gibbosity. An obscure pattern of a dusky hue may be traced on the hinder extremity, and the fore extremity is also similarly suffused.

Two examples, both males, one adult the other immature, were contained among other Swiss spiders kindly given to me some years ago by Mons. Eugène Simon. It is most probable that a series of specimens would show a richer colouring, and a more definite pattern than could be traced in these two examples, which had apparently not yet attained their full development in these respects. In general appearance the present species shows some resemblance to *Theridion pallens* Bl., but the decided difference of the thoracic markings, as well as the form of the abdomen, and the details of the palpal organs, will serve to distinguish them without difficulty.

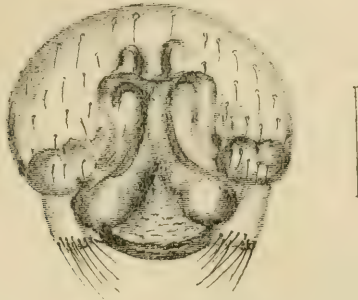
Description of *Tarentula lessertii*, sp. n. (Text-fig. 52.)

Adult female. Length $6\frac{1}{2}$ lines.

Of normal general form. The *cephalothorax* is of a dark brown colour, with a broad central longitudinal straight band of a paler hue, without lateral constriction, and clothed densely with short hoary hairs; the normal lateral converging indentations are marked by rather darker lines or narrow stripes.

The *eye-area* is dark blackish at the sides and in front; the quadrangle of the four posterior eyes is rather broader than long, and its anterior side is shortest; the two anterior eyes are separated by less than a diameter's interval, and the anterior curved row of four eyes (of which the two centrals are much the largest) are separated by about equal intervals.

Text-fig. 52.

*Tarantula lessertii*.

"Epigyne," ♀.

The *legs* are of moderate length and strength (4. 1. 2. 3), their colour is a uniform yellow-brown without any annuli; the normal spines are rather slender. The *palpi* are similar in colour to the legs. *Falces* normal and of a deep blackish-brown hue; *sternum* dark brown. *Abdomen* dark yellow-brown, its fore-side above abundantly clothed with grey hairs, with the characteristic central longitudinal marking on the fore part of the upper side clothed with hoary hairs, margined with a black line, and followed towards the spinners with a series of indistinct angular lines, or chevrons. The under side of the abdomen is of a uniform paler yellowish-brown colour than the upper side, and clothed with short hoary hairs. The abdominal markings, however, were much obscured by the rather shrunken condition of the abdomen. The epigyne is of a very distinct and characteristic form (see text-fig. 52).

The example above described has been examined by Dr. Roger de Lessert, and its species is unknown to him. I have not been able to identify it with any known continental species, and am therefore induced to describe it as new to science. It was taken during a tour in Switzerland and kindly sent to me by Mr. Henry Speyer of Reigate.

22. On the Blood-Parasites found in Animals in the Zoological Gardens during the four years 1908-1911. By H. G. PLIMMER, F.R.S., F.Z.S., Pres.R.M.S., Pathologist to the Society.

[Received March 2, 1912: Read March 5, 1912.]

(Plates XLIX.-LV.*)

During the last four years I have examined the blood of every mammal, bird, reptile, and batrachian which has died in the Zoological Gardens, 6430 in all. In 447 of these, that is about 7 per cent., I have found blood-parasites. These 447 affected animals belonged to 256 different species, as in many cases the same parasite was found in several animals of the same kind.

Many of these parasites are described or recorded here for the first time; in other cases the hosts are new. In the tables which follow I have indicated those which are new, or in new hosts, by placing asterisks against the names of the animals in which they were found. In spite of much generous help from Mr. R. I. Pocock, F.R.S., Mr. Seth-Smith, and Dr. R. T. Leiper, to whom my best thanks are due, it is impossible to be quite certain that I have not given myself too much credit, partly on account of the large amount of scattered literature on the subject, and partly on account of the constant change of names of animals on the part of zoologists.

Although the importance of the study of blood-parasites has only been recognised in comparatively recent years—that is since 1880, when Laveran discovered the hematozoon of malaria in the military hospital of Constantine—it should be remembered that the first mention of a blood-parasite dates from 1841, when Valentin described an “entozoon”—as he called it—in the blood of a fish, *Salmo fario*. Nowadays the importance of these parasites is well recognised, as well as the necessity of studying them comparatively, since we know that many of the gravest diseases of man and of animals are caused by them. I need only mention such diseases as malaria, syphilis, sleeping-sickness, and kala-azar of man, and trypanosomiasis (in its various forms), Texas fever, and the coccidiosis of animals, to remind you of this.

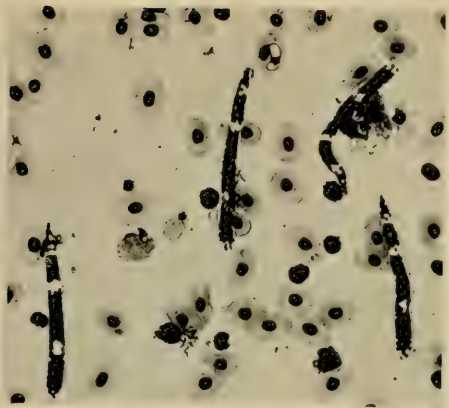
I have not attempted to give names to any of those parasites described here for the first time. In the present state of our knowledge it seems better to tabulate the hosts and give the general characteristics, or type, of the parasite. The custom of naming as new—very often with very absurd names—every similar parasite found in a new host is, I think, a very bad one. We can only name them reasonably when we know a great deal more about them than we do at present.

The parasitic organisms I have found in the blood of animals

* For explanation of the Plates see p. 417.



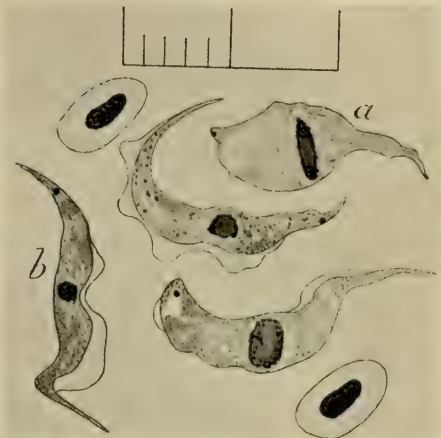
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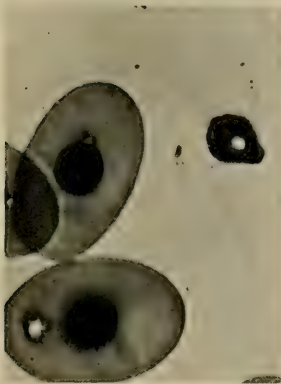
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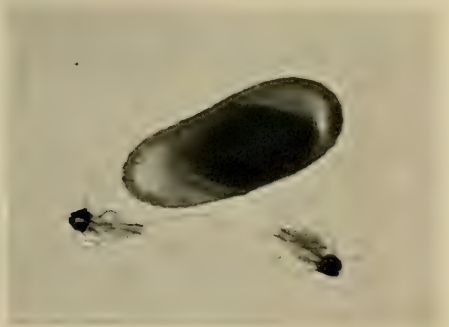
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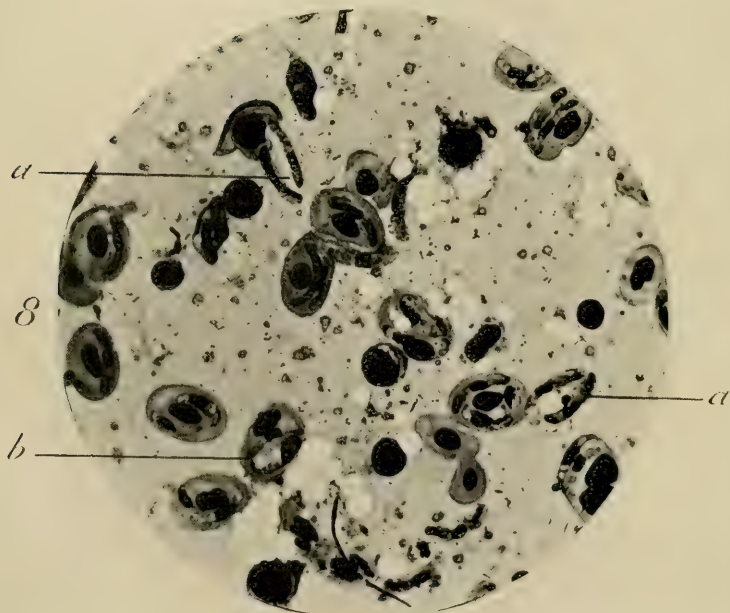
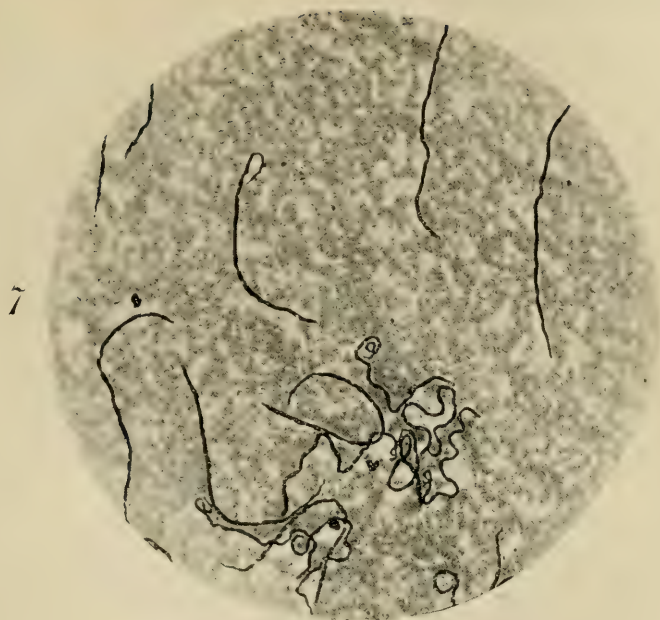
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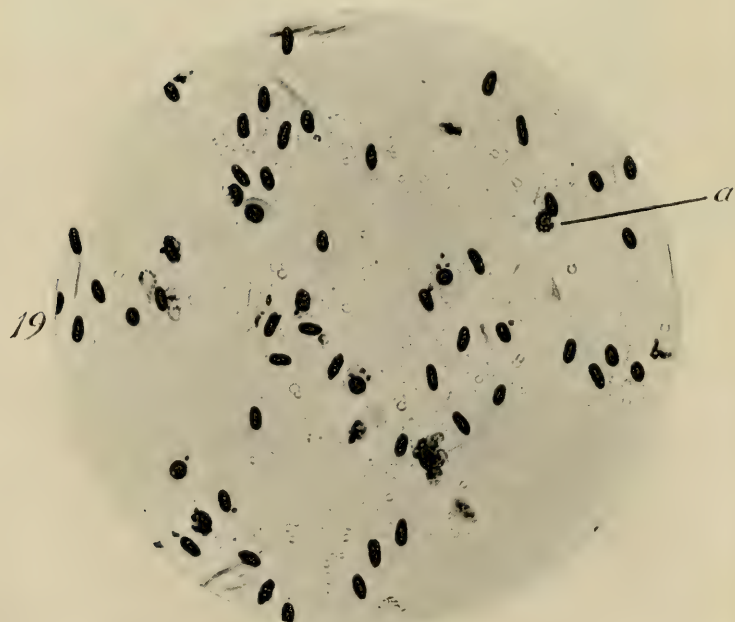
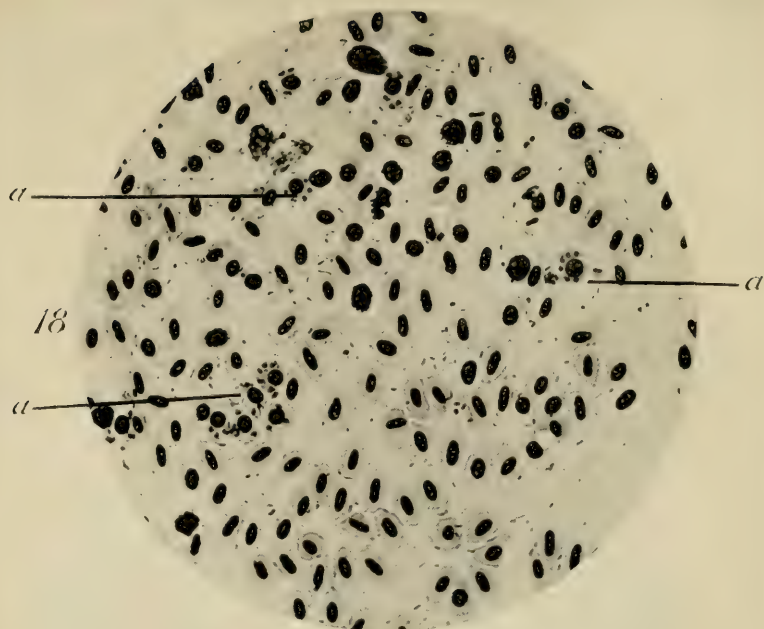


BLOOD PARASITES.



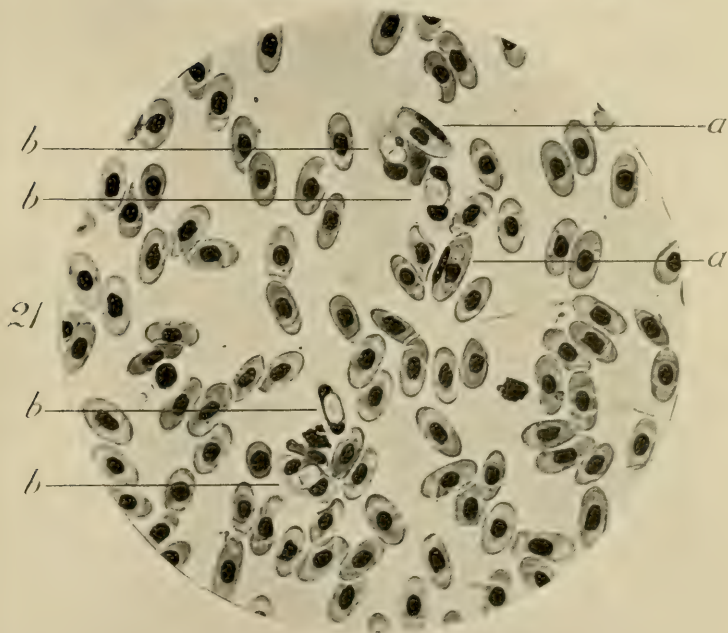
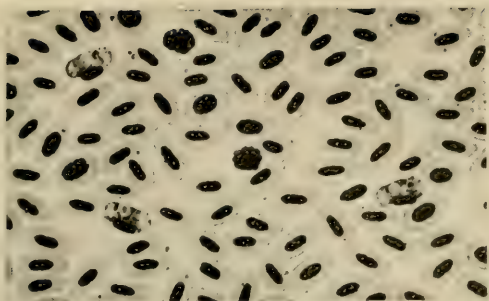
BLOOD PARASITES.





BLOOD PARASITES.

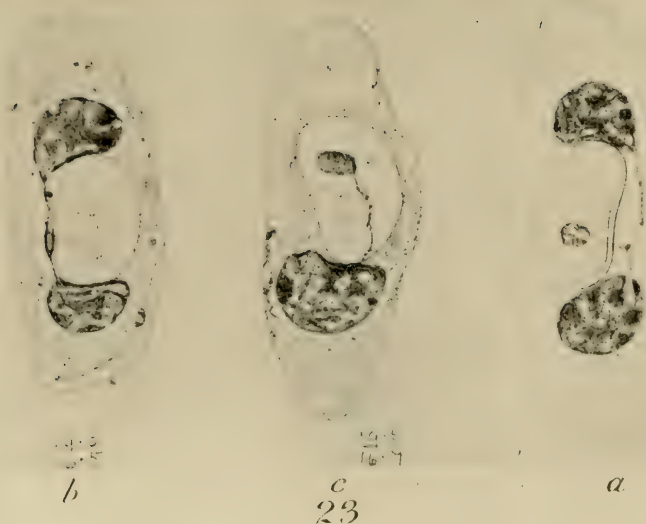
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22



BLOOD PARASITES.



in the Gardens belong to the two great groups of the Protozoa and the Worms, and, as regards the elements of the blood, they are either extra-corpuseular or intra-corpuseular.

I will begin with the extra-corpuseular parasites, those which live in the serum, and these are the nematode worms, the spirochetes, the trypanosomes, and other flagellates.

Firstly, the nematode worms—they all belong to the class *Filaria*. The embryos only are found in the blood, as the adult filariæ could not pass through the capillaries. These microfilariæ are the least harmful to their hosts of any of the blood-parasites, and all the pathological effects we know of filariæ are due to the adult worms, which have been found only in a very small proportion of the cases here. The embryos are generally surrounded by a fine capsule, which is cast off when they enter into the body of the mosquito, when their further development takes place.

I have found microfilariæ in the blood of 15 mammals of 13 different species, in 101 birds of 74 different species, and in 13 reptiles of 5 different species; and filariæ have not been found before in 88 out of these 92 species of animals, and are new, at any rate as regards hosts. The animals in which they have been found have come from all parts of the world, the largest number from the Americas, but the following list will show how wide-spread the infection is.

EMBRYO FILARIE FOUND IN THE BLOOD OF MAMMALS.

(All are either new hosts or new parasites, or both, except those marked with an asterisk.)

NAME.	HABITAT.	TYPE OF FILARIA.
Suricate (<i>Suricata suricatta</i>)	S. Africa.	Long.
Black-handed Spider Monkey (<i>Ateles geoffroyi</i>).	C. America.	Long.
Black-headed Lemur (<i>Lemur mungos</i>).	Madagascar.	Long and slender.
Crowned Lemur (<i>Lemur coronatus</i>)...	do.	Very long, striated.
White-fronted Capuchin (<i>Cebus albifrons</i>).	Ecuador.	Medium, thick.
Golden Cat (<i>Felis temmincki</i>)	Sumatra.	Long.
Bridled Wallaby (<i>Onychogale frenata</i>).	N. S. Wales.	Long.
Rat-tailed Opossum (<i>Didelphys nudicaudata</i>).	S. America.	Medium.
Collared Peccary (<i>Tayassu tajacu</i>) ...	do.	Long.
3 Pinche Marmosets (<i>Leontocebus oedipus</i>).	Colombia.	Long.
Lion Marmoset (<i>Leontocebus rosalia</i>).	Brazil.	Long.
Javan Chevrotain (<i>Tragulus javanicus</i>).	Java.	Long.
Ant-eater (<i>Myrmecophaga tridactyla</i>)	S. America.	Medium.

BIRDS.

Himalayan Whistling Thrush (<i>Myiophoneus temmincki</i>).	N. India.	Short.
Lanceolated Jay (<i>Garrulus lanceolatus</i>).	do.	Short.

BIRDS (*continued*).

NAME.	HABITAT.	TYPE.
Spotted Emerald Tanager (<i>Calliste guttata</i>).	S. America.	Short, thick.
2 Great-billed Touracous (<i>Turacus macrorhynchus</i>).	W. Africa.	Short, straight.
Wood-Thrush (<i>Turdus mustelinus</i>)...	N. America.	do.
*3 Blue-faced Honey-eaters (<i>Entomyza cyanotis</i>).	Australia.	Short, thick.
Sooty Crow Shrike (<i>Strepera fuliginosa</i>).	do.	Long, edges serrated.
*2 Black-backed Piping Crows (<i>Gymnorhina tibicen</i>).	do.	Short, straight.
Ultramarine Jay (<i>Aphelocoma ultramarina</i>).	Mexico.	Short, thin.
Stanley Parrakeet (<i>Platycercus icterotis</i>).	W. Australia.	Short, straight.
Black-headed Cat-Bird (<i>Ælurædus melanocephalus</i>).	New Guinea.	Short, thick.
6 King Birds of Paradise (<i>Cicinnurus regius</i>).	do.	Very short, thick.
4 Lawes' Birds of Paradise (<i>Parotia lawesi</i>).	do.	2 kinds: one long and thick, the other short.
2 Count Raggi's Birds of Paradise (<i>Paradisea raggiana</i>).	do.	Short.
Red-winged Francolin (<i>Francolinus garipeensis</i>).	S. Africa.	Small.
Common Cow-Bird (<i>Molothrus pecoris</i>).	N. America.	Short.
2 Orange-cheeked Waxbills (<i>Estrela melpoda</i>).	W. Africa.	Medium.
Red-backed Shrike (<i>Lanius collurio</i>).	Europe.	Long.
Banded Aracari (<i>Pteroglossus torquatus</i>).	C. America.	Short, straight.
Cuban Mocking Thrush (<i>Mimocichla rubripes</i>).	N. America.	do.
Crimson-eared Waxbill (<i>Estrela phœnicotis</i>).	W. Africa.	Very long.
Black-crested Cardinal (<i>Gubernatrix cristata</i>).	S. America.	Short.
Violet Manucode (<i>Phonygama chalybeata</i>).	New Guinea.	2 kinds: one long and one short.
Fire-red Finch (<i>Spermophila minuta</i>).	Venezuela.	Long.
American Robin (<i>Turdus migratorius</i>).	N. America.	Long.
Red-capped Parrot (<i>Pionopsittacus pileatus</i>).	Brazil.	Short, thick.
White-bellied Plumed Dove (<i>Lophophaps leucogaster</i>).	N. Australia.	Long.
Orange-headed Thrush (<i>Geocichla citrina</i>).	India.	2 kinds: one long and one short.
2 Violet Tanagers (<i>Euphonia violacea</i>).	C. America.	Medium, thick.
Blue-winged Tanager (<i>Calliste cyanoptera</i>).	S. America.	Long.
Whydah Bird (<i>Urobrachya albonotata</i>).	S. Africa.	Long.
*Garrulous Honey-cater (<i>Myzantha garrula</i>).	Australia.	Short.
2 Brazilian Hangnests (<i>Icterus jamaicai</i>).	Brazil.	Long, thick.
2 Jay Thrushes (<i>Garrulax leucolophus</i>).	N. India.	Medium.

NAME.	HABITAT.	TYPE.
6 Green-billed Toucans (<i>Ramphastos dicolorus</i>).	Guiana.	Short, very thick.
Grass Finch (<i>Erythrura prasina</i>) ...	Sumatra.	Long, thin.
Baillon's Aracari (<i>Andigena bailloni</i>)	Brazil.	Thick.
Fire Finch (<i>Lagonosticta senegala</i>).	W. Africa.	Long, thin.
Blue-cheeked Barbet (<i>Megalema asiatica</i>).	India.	Long, thin.
Shama (<i>Cittocinclra macrura</i>)	do.	Long.
Dial Bird (<i>Copsychus saularis</i>)	do.	Short, thin.
White-collared Ouzel (<i>Merula albo-cincta</i>).	do.	Short, thick.
Song Sparrow (<i>Melospiza pusilla</i>) ...	N. America.	Medium, thick.
Cat-Bird (<i>Galeoscoptes carolinensis</i>).	do.	Short, thick.
Orange Weaver-Bird (<i>Euplectes franciscana</i>).	Africa.	2 kinds: one short, and one long with very pointed ends.
Beautiful Wood-Hawk (<i>Dryotrichis spectabilis</i>).	W. Africa.	Long.
Rose-breasted Grosbeak (<i>Hedymeles ludovicianus</i>).	N. America.	Short.
Mexican Blue Jay (<i>Cyanocorax luxuosus</i>).	Mexico.	Medium, straight.
Yellow-bellied Tanager (<i>Calliste flaviventris</i>).	S. America.	Long.
Scarlet Cardinal (<i>Cardinalis phoeniceus</i>).	do.	Short to medium, thick.
Baltimore Hangnest (<i>Icterus baltimore</i>).	N. America.	Long.
3 Blue Tanagers (<i>Tanagra episcopus</i>).	S. America.	Short, thick.
Green-tailed Towhee (<i>Oreospiza chlorura</i>).	N. America.	Short, straight.
Allied Saltator (<i>Saltator senilis</i>) ...	Brazil.	Long.
Thick-billed Violet Tanager (<i>Euphonia lanirostris</i>).	do.	Long, thick.
Naked-eyed Pigeon (<i>Columba gymnophthalma</i>).	Venezuela.	Long.
2 Yellow-winged Sugar-birds (<i>Cæreba cyanea</i>).	S. America.	Short, thick.
Lavender-backed Finch (<i>Spermophila castaneiventris</i>).	Guiana.	Very long.
Black Manucode (<i>Manucodia atra</i>)...	Aru Islands.	Short.
Black-throated Hangnest (<i>Icterus gularis</i>).	Mexico.	Short, straight.
3 Blue Birds (<i>Sialia sialis</i>).....	N. America.	Short.
Brown-eared Bulbul (<i>Hemixus flava</i>)	India.	Medium.
Chilian Starling (<i>Curæus aterrimus</i>).	Chili.	Long.
White-throated Jay Thrush (<i>Garrulax albogularis</i>).	India.	Short, thick, no vacuole.
Rainbow Bunting (<i>Cyanospiza leclancheri</i>).	Mexico.	Long, very pointed.
Rufous-necked Tanager (<i>Calliste cayana</i>).	S. America.	Long, thick.
Levaillant's Francolin (<i>Francolinus levaillanti</i>).	Cape Colony.	Long, thick.
Golden-eyed Babbler (<i>Chrysomma sinense</i>).	India.	Long.
Scoter (<i>Edemia nigra</i>)	British Isles.	Striated.
Grey-necked Serin Finch (<i>Serinus canicollis</i>).	S. Africa.	Long.

BIRDS (*continued*).

NAME.	HABITAT.	TYPE.
Capueira Partridge (<i>Odontophorus capueira</i>).	S. America.	Long.
Occipital Blue Pie (<i>Urocissa occipitalis</i>).	India.	Short.
Barred Dove (<i>Geopelia striata</i>)	do.	Short, very thick.
White-backed Piping Crow (<i>Gymnorhina leuconota</i>).	Australia.	Short, thick.

REPTILES AND BATRACHIANS.

Bearded Lizard (<i>Amphibolurus barbatus</i>).	Australia.	Short, thick.
Spiny-tailed Iguana (<i>Cyclura acanthura</i>).	C. America.	do.
8 Giant Toads (<i>Bufo marinus</i>)	S. America.	do.
Pine Snake (<i>Pituophis sayi</i>)	N. America.	Long.
*2 Edible Frogs (<i>Rana esculenta</i>)	Europe.	Short.

I now come to the Protozoa, and will take first a spirochete, which belongs to the so-called Proflagellata. The spirochetes are important as being the cause of such diseases as relapsing fever, tick fever, and syphilis.

This particular one was found in the blood of a Monkey—*Cercopithecus sabæus*—and is of the type of *Spirochaeta recurrentis*, the cause of relapsing fever.

SPIROCHÆTA FOUND IN THE BLOOD OF A

NAME.	HABITAT.	CHARACTER.
Green Monkey (<i>Cercopithecus sabæus</i>).	Sierra Leone.	Like <i>Sp. recurrentis</i> .

The next in order are the Flagellates, and of these I will take first the Trypanosomes, which are flagellated organisms living in the blood serum. They are the cause of many deadly diseases in man and animals.

I have found Trypanosomes in 50 mammals, 7 birds, and 3 amphibia. 49 of the mammals were ordinary rats, out of 500 examined at the Gardens for another purpose, in which the ordinary rat trypanosome, *Trypanosoma lewisi*, was found. The other mammal was a Fat Mouse (*Steatomys pratensis*) from S. Africa, in which trypanosomes have not hitherto been described. The bird trypanosomes are all new in these particular birds; but they would appear to belong to the general type of *Trypanosoma avium*. These bird trypanosomes are quite different to the mammalian variety: they are very large and thick, they stain densely and indistinctly, and they move very slowly. The spleens of the infected birds were large and their blood anemic. The trypanosomes found in reptiles were all of the type of *Trypanosoma rotatorium*, which was the one described by Gruby in 1843. It has not been described before in the Tree Frog (*Hyla venulosa*).

TRYPANOSOMES FOUND IN THE BLOOD OF MAMMALS.

NAME.	HABITAT.	CHARACTER.
Fat Mouse (<i>Steatomys pratensis</i>) ..	S. Africa.	Of Nagana type.
*49 Rats (<i>Epimys norvegicus</i>)	England.	<i>T. lewisi</i> .

BIRDS.

Red-winged Francolin (<i>Fringilla garruloides</i>) ..	S. Africa.	<i>T. avium</i> type.
Chukar Partridge (<i>Caccabis chukar</i>)	India.	do.
Marsh Bird (<i>Leistes guianensis</i>)	Demerara.	do.
Waxbill (<i>Estrilda melodia</i>)	Australia.	do.
Levaillant's Francolin (<i>Fringilla levaillantii</i>) ..	Cape Colony.	do.
Dial Bird (<i>Copsychus saularis</i>)	India.	do.
Bower Bird (<i>Amblyornis subalaris</i>)	New Guinea.	do.

BATRACHIANS.

*Edible Frog (<i>Rana esculenta</i>)	Europe.	<i>T. rotatorium</i> type.
*Tree Frog (<i>Hyla arborea</i>)	do.	do.
Tree Frog (<i>Hyla venulosa</i>)	S. America.	do.

There are certain flagellated organisms which may appear in the blood and live there not as actual parasites, but accidentally. In reptiles there are certain kinds of inflammation of the intestine, accompanied by ulceration, which cause the walls of the intestine to become permeable, so that some of the flagellated organisms which are often found there are able to get into the blood and live there. The alteration of structure of the intestine during the inanition of hibernation is also favourable to the passage of organisms through the intestinal wall. I have found these flagellates in the blood of 8 reptiles, and they have been either varieties of *Hexamitus*, found first by Dujardin in 1841 in the frog's intestine, or of *Trichomonas*: the former in the frog and tortoises, the latter in the snake.

The only other mention of these organisms in the blood is by Danilevsky, in 1889, who found the *Hexamitus* in the blood of *Emys lutaria* and *Rana esculenta*, so that those given in the following list are all new hosts for this kind of infection. In the *Hexamitus* infections there was general œdema of the tissues and ascites, and the organisms were found also in the transudation.

INTESTINAL ORGANISMS FOUND IN THE BLOOD OF REPTILES AND BATRACHIANS.

NAME.	HABITAT.	TYPE OF PARASITE.
Bull Frog (<i>Rana catesbeiana</i>)	N. America.	<i>Hexamitus</i> .
Leopardine Snake (<i>Coluber leopardinus</i>) ..	Europe.	<i>Trichomonas</i> .
Indian Cobra (<i>Naia tripudians</i>)	India.	do.
Box Tortoises (<i>Cistudo carolina</i>)	N. America.	<i>Hexamitus</i> .
Three-banded Terrapin (<i>Cyclemys trifasciata</i>) ..	E. Indies.	do.
Hog-nosed Snake (<i>Heterodon simus</i>)	N. America.	<i>Trichomonas</i> .
West-African Python (<i>Python sebae</i>)	W. Africa.	do.
Angulated Tortoise (<i>Testudo angulata</i>) ..	S. Africa.	<i>Hexamitus</i> .

I now come to the intracellular parasites, and will take first the *Hæmogregarines*, which are intracellular parasites occurring chiefly in the reptile group, and, so far as my experience here goes, entirely in that group. I have found them here in 150 reptiles, of 67 different species, and in 41 of these for the first time. The schizont is found generally in the erythrocyte of the host, and is an elongated body with a well-marked nucleus, and with no pigment. Schizogony occurs generally in the internal organs, especially in the lungs; this stage, however, has not yet been observed in all cases. They vary much in their effect on the cell and on the nucleus, and I have indicated in the following table the most obvious of these effects. With some hæmogregarines very little change takes place in the cell; with others the cell gets smaller and out of shape; with others it gets enormously enlarged and de hæmoglobinised. Others again destroy the nucleus, like the *Karyolysus* of lizards and snakes. Some infections are very severe, scarcely a cell is unaffected, and there may be sometimes as many as four parasites in a cell. I have found a very remarkable one of a new type in a Bengal Monitor. This parasite divides the nucleus of the cell into two parts which remain connected by a thread of nuclear material which has a tiny enlargement at its central point. I have found that the schizogony of this parasite takes place in the lung, several stages of which are shown in the Plates.

HÆMOGEGARINES FOUND IN THE BLOOD OF REPTILES AND BATRACHIANS.

NAME.	HABITAT.	CHARACTERS.
*3 Moorish Geckos (<i>Tarentola mauritanica</i>).	Mediterranean.	Parasites large and doubled over at one end, sometimes at both.
Bengal Monitor (<i>Varanus bengalensis</i>).	India.	Nucleus of cell divided into two by the parasite, with connecting thread. Schizogony in lungs.
*2 Rat-tailed Serpents (<i>Lachesis lanceolatus</i>).	S. America.	Host-cells enlarged.
2 Teguxins (<i>Tupinambis teguixin</i>).	do.	Parasites bulky and very full of granules; many with only remains of nucleus attached.
3 Black-spotted Lizards (<i>Algiroides nigropunctatus</i>).	Adriatic.	Short to medium, some bottle-shaped; chromidia at both ends; free sporonts in all.
*9 Indigo Snakes (<i>Coluber corais</i>)...	C. America.	Host-cells enlarged and de hæmoglobinised.
Viraceous Snake (<i>Tarbophis fallax</i>)	S. Europe.	Medium; cells unaltered.
*3 Lace Monitors (<i>Varanus varius</i>).	Australia.	Parasites large and contain granules; cells unaltered.
*Horseshoe Snake (<i>Zamenis hippocrepis</i>).	S. Europe.	Bulky; turned over at one end.
*6 Indian Pythons (<i>Python molurus</i>).	India.	Host-cells often deformed; generally diminished in size.
20 Diamond Rattlesnakes (<i>Crotalus atrox</i>).	Texas.	Host-cells enlarged and de hæmoglobinised.
*King Snake (<i>Coronella getula</i>)	N. America.	Very thick, short forms; some free sporonts which are long and pointed.

NAME.	HABITAT.	CHARACTERS.
*Hoary Snake (<i>Pseudaspis cana</i>)	S. Africa.	Short, bulky, and full of granules; host-cells deformed.
Puff Adder (<i>Bitis arietans</i>)	do.	Medium; host-cells unaltered.
*Mexican Snake (<i>Coluber melano-leucus</i>).	Mexico.	Host-cells very much enlarged.
Senegal Chameleon (<i>Chameleon senegalensis</i>).	W. Africa.	Short, bulky.
*6 Cobras (<i>Naja tripudians</i>)	India.	Long parasites; cells unaltered.
Large Grieved Tortoise (<i>Podocnemis expansa</i>).	S. America.	Bulky and granular, with eccentric nucleus.
*Alligator (<i>Alligator mississippiensis</i>).	N. America.	Parasites small, granular; nucleus often eccentric.
2 Clarke's Lizards (<i>Sceloporus clarkii</i>).	do.	Long, with dense nuclei, some hooked; cells greatly altered.
*3 Diamond Pythons (<i>Python apilotes</i>).	Australia.	Very long, doubled over.
Gallot's Lizard (<i>Lacerta galloti</i>)...	Canary Islands.	Adherent to nucleus of host-cell; granules at both ends.
*5 Indian Rat Snakes (<i>Zamenis mucosa</i>).	India.	Medium sized; cells unaltered.
*Aesculapian Snake (<i>Coluber longissimus</i>).	Europe.	Medium sized; adherent to nucleus of host-cell.
*2 Common Boas (<i>Boa constrictor</i>).	S. America.	Long and hooked; some cells enlarged.
Reeves's Terrapin (<i>Damonis reevesi</i>)	China.	Short, thick, with eccentric nuclei.
*Reticulated Python (<i>Python reticulatus</i>).	E. Indies.	Long, doubled over, cells enlarged.
4 Chicken Snakes (<i>Coluber obsoletus</i>).	N. America.	Host-cells enlarged.
2 Corn Snakes (<i>Coluber guttatus</i>).	do.	do.
Banded-tailed Snake (<i>Leptophis bicercus</i>).	S. America.	Medium; cells unaltered.
4 Spiny-tailed Snakes (<i>Cyclura acanthura</i>).	C. America.	Large and granular, cell nearly filled; nucleus compressed and dense.
*3 Coach-whip Snakes (<i>Zamenis flagelliformis</i>).	N. America.	Host-cells deformed; parasites long and hooked at one end, later doubled over.
*3 Pond Tortoises (<i>Emys orbicularis</i>).	S. Europe.	Short and thick, with eccentric nuclei; a few very thin and doubled over.
Painted Terrapin (<i>Chrysemys picta</i>).	N. America.	Short and thick, with granules; cells deformed.
Smaller Rattlesnake (<i>Sistrurus miliarius</i>).	do.	Long and thick, with eccentric nuclei.
Boddaert's Snake (<i>Drymobius boddaerti</i>).	C. America.	Bulky and hooked; cells deformed.
3 Black Snakes (<i>Zamenis constrictor</i>).	N. America.	Large and hooked; cells deformed.
Hog-nosed Snake (<i>Heterodon sinuatus</i>).	do.	Long; cells enlarged and ultimately dehaemoglobinised.
Moccasin Snake (<i>Tropidonatus fasciatus</i>).	do.	Thin and long forms; cells unaltered.
Pine Snake (<i>Pituophis sayi</i>).....	do.	Host-cells enlarged and dehaemoglobinised.
*4 Giant Toads (<i>Bufo marinus</i>).....	S. America.	Short and thick; cells unaltered.
*2 Spanish Terrapins (<i>Clemmys leprosa</i>).	Spain.	Bulky; cells deformed.
Horrid Rattlesnake (<i>Crotalus horridus</i>).	N. America.	Long and thin; cells unaltered.
4 Bell's Cinyxes (<i>Cinixys belliana</i>).	C. Africa.	Short, thick.

NAME.	HABITAT.	CHARACTERS.
Black Sternother (<i>Sternotherus niger</i>).	W. Africa.	Medium sized.
Hasselquist's Gecko (<i>Ptyodactylus lobatus</i>).	Egypt.	Short; cells deformed.
2 Speckled Terrapins (<i>Clemmys guttata</i>).	N. America.	Short; bulky; nucleus eccentric.
Green Tree Viper (<i>Atheris chlor-echis</i>).	W. Africa.	Long and thin.
Three-keeled Terrapin (<i>Staurotypus triporcatus</i>).	C. America.	Medium.
Egyptian Gecko (<i>Tarentola annularis</i>).	Egypt.	Short, bulky; cells deformed.
Hilaire's Terrapin (<i>Hydraspis hilairei</i>).	Brazil.	Long, doubled over.
*4 Eyed Lizards (<i>Lacerta ocellata</i>).	S. Europe.	Host-cells enlarged and some de-hæmoglobinised. Long, thin; some bottle-shaped.
*Nilotic Monitor (<i>Varanus niloticus</i>).	Africa.	Medium, thick.
*2 Cook's Tree Boas (<i>Corallus cooki</i>).	W. Indies.	Host-cells deformed, short; nucleus not central.
Green Tree Snake (<i>Dendraspis viridis</i>).	W. Africa.	Large, often two in cell which is not enlarged.
*2 Russell's Vipers (<i>Vipera russelli</i>).	India.	Bulky: cells deformed.
*2 Eryxs (<i>Eryx johnei</i>).....	do.	Long, with hooked end.
3 Dahl's Snakes (<i>Zamenis dahl</i>)...	S. Europe.	Long, thin; turned over at both ends.
*Confluent Rattlesnake (<i>Crotalus confluentus</i>).	N. America.	Long, doubled over.
Glass Snake (<i>Ophiosaurus apus</i>)...	S. Europe.	Large and granular; host-cells elongated.
Long-nosed Viper (<i>Vipera ammodytes</i>).	do.	Bulky; cells not enlarged.
Tuberculated Iguana (<i>Iguana tuberculata</i>).	C. America.	Short, stout, sometimes round.
Peloponnesian Lizard (<i>Lacerta peloponnesiaca</i>).	S. Europe.	Short.
Madagascar Boa (<i>Boa madagascariensis</i>).	Madagascar.	Short, thick; cells deformed. Schizogony found in liver.
West African Python (<i>Python sebae</i>).	Tropical Africa.	Medium sized.
2 Dark Green Snakes (<i>Zamenis gemonensis</i>).	Europe.	Cells enlarged and de-hæmoglobinised; parasites long and thin.
Square-marked Toad (<i>Bufo regularis</i>).	Africa.	Short and very thick.

The next group is that of the Plasmodidæ, to which the various malarias belong.

I have found only one mammal—a Green Monkey—infected with, malaria, probably *Plasmodium kochi*. It is uncertain, because I could only get certain stages; the host-cells do not seem to be greatly altered.

In the birds there are two kinds of intra-corpuseular parasites, the *Plasmodium præcox* and *Hemoproteus danilewskyi*, which have been sometimes confused, but are really entirely distinct. The *Plasmodium præcox* has many points of similarity to the parasites of human malaria, and in many stages is so like that it can only be differentiated by the presence of the oval nucleus of

the bird's erythrocyte. I have found *Plasmodium præcox* in 20 different species of birds, in none of which has it been recorded before. Geographically the distribution of the 21 birds in which I have found this parasite is as follows:—Europe 1, Asia 4, Africa 5, Americas 8, Australia 3. It is a deadly disease in birds, and produces a marked anæmia, and considerable enlargement of the spleen and changes in the bone-marrow.

I have found Plasmodia in 6 reptiles of 5 different species, in all for the first time. They all probably fall under the heading of *Hæmocystidium*. They all have pigment, and when large have rather the appearance of *Hæmoproteus*. The cells are not altered.

PLASMODIAL PARASITES FOUND IN THE BLOOD OF

MAMMALS.—*Plasmodium kochi*.

NAME.	HABITAT.
*Green Monkey (<i>Cercopithecus sabæus</i>)	Sierra Leone.

BIRDS.—*Plasmodium præcox*.

Long-tailed Glossy Starling (<i>Lamprotornis æneus</i>) .	W. Africa.
Japanese Hawfinch (<i>Coccothraustes melanura</i>)	Japan.
2 Crowned Cranes (<i>Balearia regulorum</i>) ..	S. Africa.
Orange-cheeked Waxbill (<i>Estrela melpoda</i>)	W. Africa.
Small Hill Mynah (<i>Gracula religiosa</i>).....	India.
Red-and-Blue Macaw (<i>Ara macao</i>)	C. America.
Tambourine Pigeon (<i>Tympanistria bicolor</i>).....	W. Africa.
Red-eared Bulbul (<i>Pycnonotus jocosus</i>)	India.
Nutcracker (<i>Nucifraga caryocatactes</i>).....	Europe.
Yellow-breasted Tanager (<i>Calliste thoracica</i>)	Brazil.
Blue Sugar-Bird (<i>Dacnis cayana</i>)	S. America.
Brazilian Hangnest (<i>Icterus jamaicæ</i>).....	Brazil.
Ox-Bird (<i>Textor alector</i>)	W. Africa.
Flycatcher (<i>Stoparola melanops</i>)	Australia.
Jay-Thrush (<i>Garrular leucolophus</i>)	N. India.
Mexican Finch (<i>Carpodacus mexicanus</i>)	Mexico.
Rainbow Bunting (<i>Cyanospiza teclancheri</i>) ..	Mexico.
Blue-tailed Fruit Pigeon (<i>Carpophaga concinna</i>) .	Arn Islands.
Cuban Finch (<i>Phonipara canora</i>)	Cuba.
Scaly Dove (<i>Scardafella squamosa</i>)	S. America.

REPTILES.—*Hæmocystidium*.

Bell's Cinixys (<i>Cynixis belliana</i>)	Africa.
Three-tailed Terrapin (<i>Staurotypus triporcatus</i>)	B. Honduras.
Painted Terrapin (<i>Chrysemys picta</i>)	N. America.
Home's Cinixys (<i>Cinixys homeana</i>)	W. Africa.
2 Eroded Cinixys (<i>Cinixys erosa</i>)	W. Africa.

The second parasite of birds is *Hamoproteus danilevskyi*, which has been found in a large number of cases; and its development is unknown. It is found first as a small irregular body in the

erythrocyte of the bird and then grows in the long axis of the cell, and turns round the end of the nucleus, and it contains pigment. It has been shown by the Sergeants and by Aragão that a species of fly—*Lynchia maura*—is the principal host. The process of fertilization in these parasites has been described by MacCallum, and it is believed that other stages are found in the lungs.

I have found these parasites in 69 birds of 48 different species, in 46 of the latter for the first time.

The following list shows that the parasite is very widely distributed. 76 of the hosts came from Africa and 42 from the Americas.

HÆMOPROTEUS DANILEWSKYI FOUND IN BIRDS.

NAME.	HABITAT.
3 Blue-winged Tanagers (<i>Calliste cyanoptera</i>)	S. America.
Bouvier's Owl (<i>Scotopelia bouvieri</i>)	Lagos.
3 Great-billed Touracous (<i>Turacus macrorhynchus</i>)	W. Africa.
Black-shouldered Tanager (<i>Calliste melanonota</i>) ...	Brazil.
Porphyrio (<i>Porphyrio madagascariensis</i>)	Madagascar.
2 Green-headed Tanagers (<i>Calliste tricolor</i>)	S. America.
Red-sided Eclectus (<i>Eclectus pectoralis</i>)	New Guinea.
White-backed Piping Crow (<i>Gymnorhina leuconota</i>)	Australia.
Hanging Parrakeet (<i>Loriculus galgulus</i>)	Malacca.
3 Brown-necked Parrots (<i>Paeocephalus fuscicollis</i>)	W. Africa.
Bower Bird (<i>Amblyornis subalaris</i>)	New Guinea.
5 Yellow-winged Sugar-birds (<i>Cœreba cyanea</i>)	S. America.
5 Maequeen's Bustards (<i>Houbara maequeeni</i>)	W. Asia.
3 King Birds of Paradise (<i>Cicinnurus regius</i>)	New Guinea.
Dial Bird (<i>Copsychus saularis</i>)	India.
*African Barn Owl (<i>Strix flammea</i>)	S. Africa.
Grenadier Weaver Bird (<i>Euplectes oryx</i>)	W. Africa.
Parrot Finch (<i>Erythrura psittacea</i>)	New Caledonia.
Australian Sheldrake (<i>Tadorna tadornoides</i>)	Australia.
2 White-crested Touracous (<i>Turacus corythaix</i>) ...	S. Africa.
Mexican Haugnest (<i>Cassiculus melanicterus</i>)	Mexico.
Palm Tanager (<i>Tanagra palmarum</i>)	S. America.
Honey-eater (<i>Ptilotis fusca</i>)	Australia.
Schlegel's Dove (<i>Calopelia puella</i>)	W. Africa.
Cut-throat Finch (<i>Amadina fasciata</i>)	W. Africa.
Scops Owl (<i>Scops leucotis</i>)	Gambia.
Black-throated Lorrikeet (<i>Trichoglossus nigrigularis</i>)	New Guinea.
Grass Finch (<i>Erythrura prasina</i>)	Sumatra.
Baer's Duck (<i>Fuligula baeri</i>)	India.
2 Kestrels (<i>Tinnunculus alaudarius</i>)	British Isles.
Spotted-backed Weaver (<i>Hyphantornis spilonotus</i>)	Africa.
Festive Tanager (<i>Calliste festiva</i>)	Brazil.
Rose-breasted Grosbeak (<i>Hedymeles ludovicianus</i>)	N. America.
Senegal Touraou (<i>Turacus persa</i>)	W. Africa.
*Cape Eagle-Owl (<i>Bubo capensis</i>)	S. Africa.
Hooded Siskin (<i>Chrysomitris cucullatus</i>)	N. America.
Fuscous Honey-eater (<i>Ptilotis fusca</i>)	Australia.

NAME.	HABITAT.
Whydah Bird (<i>Vidua paradisica</i>)	W. Africa.
Manchurian Crane (<i>Grus japonensis</i>)	N. China.
Lawes' Bird of Paradise (<i>Parotia lawesi</i>)	New Guinea.
Eagle-Owl (<i>Bubo maculosa</i>)	S. Africa.
Indian Roller (<i>Coracias indica</i>)	India.
Yellow-checked Tit (<i>Machlolophus xanthogenys</i>) ...	do.
2 Blue Tanagers (<i>Tanagra episcopus</i>)	S. America.
Fraser's Eagle-Owl (<i>Bubo poensis</i>)	W. Africa.
Cape Sparrow (<i>Passer arcuatus</i>)	S. Africa.
2 Purple-capped Lories (<i>Lorius domicella</i>)	Moluccas.
Purple Sugar-Bird (<i>Cereba cyanea</i>)	S. America.

One other parasite remains to be mentioned—the Leucocytozoon: this is found in the blood of birds in the form of a long, spindle-shaped, unpigmented body, about three or four times the length of a normal erythrocyte, and about one third of the breadth. Unstained they are colourless and are always free from pigment. They are rare, and at present uncertain as to position, and they occur only in the blood in the sexual forms. The dull plasma staining may indicate that the forms in the blood are macrogametes. The earlier observers of this parasite—Danilewsky and Ziemann—believed that the host-cell was a leucocyte, but Laveran has shown that it is an erythrocyte.

There would seem to be some analogy between the curious enlargement of the host-cell and the enlargement and dehaemoglobinisation of the erythrocytes of snakes, containing one of the varieties of hamogregarines mentioned before.

I have found these parasites in two birds only, both of which are new as hosts,

LEUCOCYTOZOA FOUND IN THE BLOOD OF BIRDS.

NAME.	HABITAT.
Scaup's Duck (<i>Fuligula marila</i>)	Europe.
Levaillant's Francolin (<i>Francolinus levaillanti</i>) ...	Cape Colony.

EXPLANATION OF THE PLATES.

The microphotographs were made for me by Dr. A. Norman, and the drawings were made to scale by Mr. W. S. Berridge.

The scale divisions are .01 millimetre.

PL. XLIX.

Fig. 1. Filaria in the blood of a Wallaby. $\times 250$. The capsule can be seen with a lens as a white line outside the filaria.

The blood in this case was very disorganised and there was a marked leucocytosis. In the pouch there was a very young fetus in the body-cavity of which there was one adult filaria similar to others found in the body-cavity of the mother. No embryo filariae were found in the blood of the fetus.

Fig. 2. Filariae in the blood of a Giant Toad. $\times 300$. The capsule is quite visible, and also the pointed anterior end.

These were present in large numbers.

- Fig. 3. Spirochetes in the blood of a Green Monkey. $\times 1000$.
The monkey had also malaria (not shown).
Fig. 4. Trypanosomes in the blood of a Dial Bird. They are large and thick: the one marked *a* is probably degenerating, and that marked *b* is of a different shape and stained more easily.
Fig. 5. Intestinal organism of *Trichomonas* type in the blood of a Leopardine Snake. $\times 1000$.
Fig. 6. Intestinal organisms of *Hexamitus* type in the blood of a Bull Frog.

PL. L.

- Fig. 7. Filariae in the blood of a Pinche Marmoset. $\times 135$. Present in very large numbers. The capsule is not distinguishable.
Fig. 8. Hæmogregarines in the blood of a Hog-nosed Snake. $\times 500$.
A very severe infection, nearly every erythrocyte contained one or more parasites. At *a* parasites which have escaped from the erythrocytes and are free in the blood are seen, and at *b* a cell containing so-called male and female forms.

PL. LI.

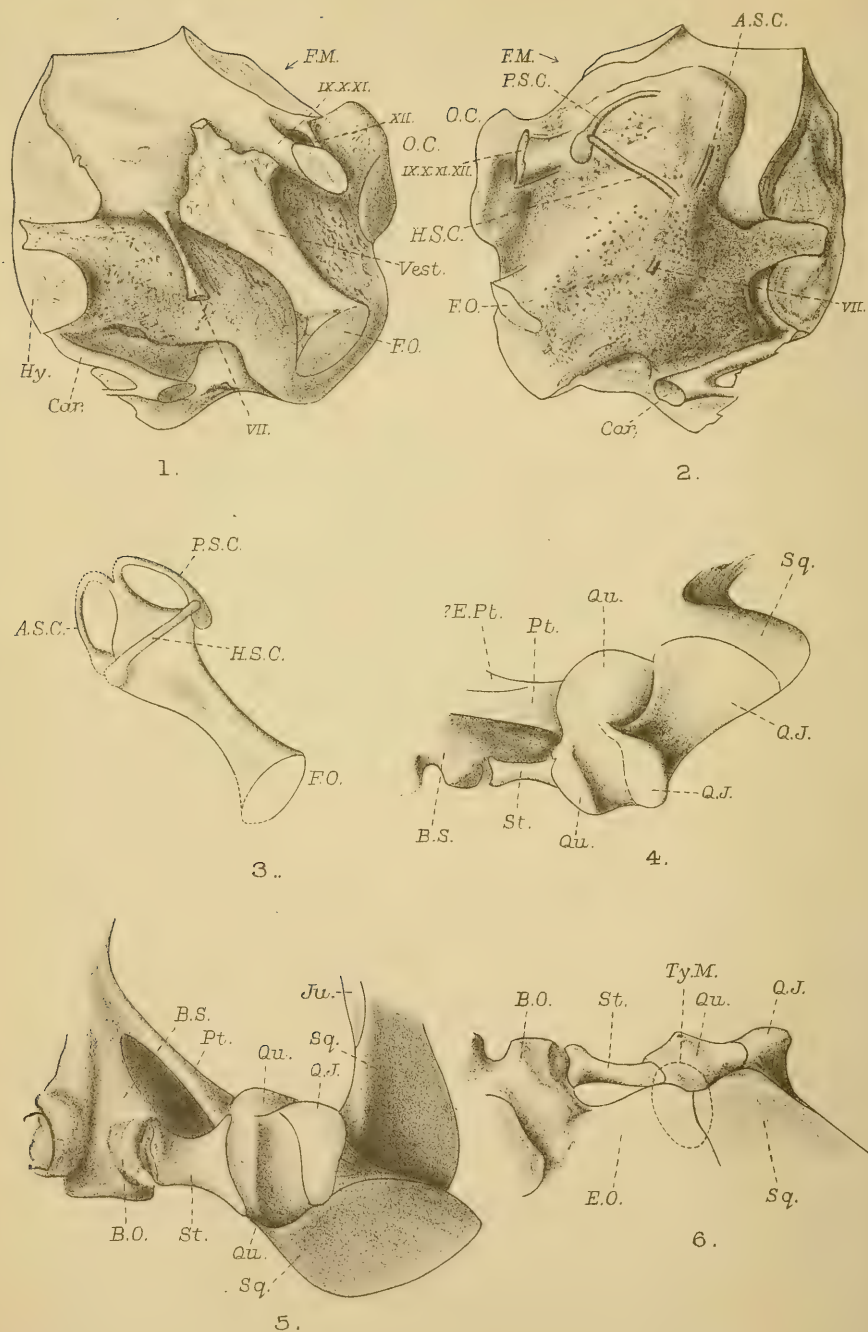
- Fig. 9. A drawing of various forms of the same *Hexamitus* type of organism of which a photograph is shown on Pl. XLIX. fig. 6.
Fig. 10. A scale-drawing of the Hæmogregarine found in the blood of a Hog-nosed Snake, of which a photograph is given on Pl. L. fig. 8.
a. An erythrocyte containing two parasites of so-called male and female types. *b*. Two parasites free in the blood, one hyaline, the other very granular. *c*. Schizogony: two cysts from the lung. *d*. Also from the lung; probably an earlier stage than *c*.
Fig. 11. A scale-drawing of Hæmogregarines in the blood of a Black Snake. At *a* are two parasites joined together by the remains of the nucleus of the erythrocyte. *b* points to a number of probable ookinete forms found in the stomach of a tick found upon the snake.
Fig. 12. Hæmogregarines in the blood of a Rat-tailed Serpent. $\times 500$. This is a late stage of the infection, showing the parasites attached to the remains of the nuclei of the erythrocytes.
Fig. 13. Hæmogregarines in the blood of a Mexican Snake. $\times 300$. At *a* can be seen infected erythrocytes which are enormously enlarged, very much thinned, and entirely dehaemoglobinised.

PL. LII.

- Fig. 14. Drawing of Hæmogregarines from the blood of a Black-spotted Lizard. Showing enlargement of the corpuscles and the various forms assumed by this parasite. At *a* is an erythrocyte very much enlarged and altered in shape and texture, and vacuolated. At *b* are two free forms, showing considerable nuclear activity and very granular protoplasm.
Fig. 15. An erythrocyte from the bone-marrow of the same Black Snake to which Fig. 11 refers. $\times 750$. It contains two hæmogregarines of the so-called male and female type.
Fig. 16. Drawing of Hæmogregarines from the blood of a Madagascar Boa. Enlarged cells containing one and two parasites. At *a* is a cyst from the lung, showing commencing schizogony.
Fig. 17. Drawing of a leucocytozoon from the blood of a Scaup's Duck. At *a* are deformed erythrocytes containing the parasite; at *b* remains of nuclei of erythrocytes; at *c* a macrogamete; and at *d* probably a microgamete.

PL. LIII.

- Fig. 18. Blood of a Brazilian Hangnest, showing infection with *Plasmodium præcox*. $\times 450$. Many of the infected cells show a multiple infection as at *a*.
Fig. 19. Blood of a Crowned Crane showing the same parasite as Fig. 18. The blood is very anæmic. There are single and multiple infections of the erythrocytes, and at *a* is a parasite breaking up into a rosette.



PL. LIV.

Fig. 20. Blood of a Palm Tanager showing infection with *Hæmoproteus danilewskyi*. Three full-sized parasites are present, and some early forms are seen in the photograph as dots in the erythrocytes.

Fig. 21. Blood of a Bengal Monitor showing an ordinary hæmogregarine and the one mentioned on p. 412 of text. $\times 450$. This is probably a double infection as no intermediate stages between these parasites can be seen.

At *a* the ordinary form of hæmogregarine is seen; those erythrocytes marked *b* contain the new type of parasite, to which reference has been made in the text. This parasite stains badly, there is a very small amount of nuclear material in it when stained by any modification of the Romanowsky method or by iron-logwood, and the altered nucleus of the erythrocyte stains very densely.

Fig. 22. Drawings of the same parasites. At *a* the ordinary hæmogregarines are shown, and at *b* the other parasite, in an early stage in the drawing to the left, and in the later stage, with the cell-nucleus divided, to the right.

PL. LV.

Fig. 23. Drawings of the new parasite.

The erythrocyte in the photograph and drawings is seen to be deformed, and eventually de hæmoglobinised (as in the cell marked *a*). At *b* is seen the tiny nodule which is generally to be found on the delicate connecting-thread between the pieces of the cell-nucleus. The cell marked *c* contains what appears to be an abortive attempt to divide the cell-nucleus equally: very few of these were found.

Fig. 24. Drawings of forms found in the lungs, showing various stages in schizogony. None of these small forms have been found in the erythrocytes. No stages were found in the other organs.

23. On the Structure of the Internal Ear and the Relations of the Basicranial Nerves in *Dicynodon*, and on the Homology of the Mammalian Auditory Ossicles. By R. BROOM, M.D., D.Sc., C.M.Z.S.

[Received January 12, 1912: Read March 5, 1912.]

(Plate LVI.* and Text-figure 53.)

Few questions connected with vertebrate morphology have given rise to a larger amount of discussion than the homology of the mammalian auditory ossicles and the connected problem of the fate of the quadrate in mammals. Most embryologists have been struck with the resemblance of the malleus and incus to an articular and quadrate; many comparative anatomists have been impressed rather with the resemblance of the mammalian auditory chain with the auditory apparatus of the Reptilia; while palæontologists, for the most part, have hesitated to believe that the incus could be the quadrate, from the difficulty of imagining the intermediate stages, and have inclined rather to believe that the quadrate has become part of the zygomatic arch, or the meniscus, or become lost, or converted into the tympanic bone.

Until a few months ago I was of opinion that the quadrate became either the meniscus or, in those few forms where a meniscus is absent, was lost. It is unnecessary to repeat the arguments

* For explanation of the Plate see p. 425.

by which I have endeavoured to maintain this position; suffice it to say that I now regard the position as untenable, since the element in the Anomodonts which I have long regarded as the tympanic now proves to be unquestionably the stapes.

In the type skull of *Dicynodon latifrons* there is a slender rod-like bone lying in the cavity which is bounded above by the exoccipital, and usually by a dumbbell-like bone below. The stout dumbbell-like bone which stretches from the basioccipital process to the quadrate I have hitherto believed to be the tympanic, and the slender rod-like bone the stapes. New evidence now shows that whatever the slender bone may be—perhaps a displaced part of the hyoid—the supposed tympanic is undoubtedly the stapes, and what I believed to be the fenestra ovalis is the foramen for the viith nerve.

Having the imperfect occiput of a moderate sized *Dicynodon*, in which the matrix was much hardened by epidote and the bone mainly calcareous, I saw it might be possible to dissolve the bone and leave a cast of the internal ear and the basicranial nerve-passages. Though on one side much of the internal ear was found to be occupied by calcite, the result of the decalcification on the whole was so satisfactory that the structure of the ear in *Dicynodon* is now almost as well known as in recent animals, and as much is known of the cranial nerves as is ever likely to be known.

The internal ear (Pl. LVI. figs. 1–3) is unlike that of any animal hitherto described, so far as I am aware. While the semicircular canals are apparently not unlike those of recent reptiles or mammals, the vestibule is very remarkably elongated and there is no trace of a cochlea.

The vestibule has an upper, somewhat triangular portion, which lies between the upper end of the canal for the viith nerve and the upper end of that for the ixth, xth, and xith nerves. In close contact with the brain cavity there is an upward extension, with which is united the canal common to the anterior and posterior semicircular canals. On the anterior and posterior sides are irregular excrescences, which are perhaps vascular spaces filled with matrix. The broadest part of the vestibule is where the ampullæ of the anterior and posterior semicircular canals are situated. From this point the vestibule passes downwards for a distance about twice as great as the maximum width. To near the middle of this descending portion there is a steady narrowing, but beyond the middle the vestibule again expands and the fenestra ovalis is about as wide as the widest part of the vestibule. The fenestra ovalis lies near the middle of the descending basioccipital process, but looks outwards and slightly downwards. This large descending process, so conspicuous in the Anomodont skull, is formed posteriorly by the basioccipital bone, and in front it is supported by the basisphenoid, but there seems considerable reason for believing that the centre portion is partly prootic and partly opisthotic. Down the descending part of the vestibule there appears to be evidence of the suture between the two otic bones.

The semicircular canals are lost from the left side of the specimen, and though they are preserved on the right side, as they are partly filled with calcite and the bone is much epidotised, it is impossible satisfactorily to decalcify the right side. Still, sufficient has been successfully accomplished to show at least a part of each canal.

The posterior semicircular canal has a distinct ampulla, which lies very close to the canal for the ixth, xth, and xith nerves. From here it passes upwards and forwards, then inwards, and lastly downwards, doubtless uniting with the upper end of the anterior canal.

The horizontal canal, though well shown in its middle region, has neither its anterior nor posterior ends displayed. The position of the canal will be better understood from the figure than from description.

The anterior semicircular canal is badly displayed. It runs mainly upwards to unite with the descending part of the posterior canal.

The cast of the posterior portion of the cranial cavity and of the basicranial nerves is beautifully preserved.

Behind the lower end of the posterior semicircular canal is seen the cast of the large canal for the ixth, xth, and xith nerves; where it leaves the cranial cavity it is slightly extended antero-posteriorly, but where it leaves the skull it is flattened a little vertically.

The canal for the xiith nerve passes down a short distance behind the jugular foramen, and unites with it before it leaves the skull. The fact that the xiith nerve has only a single canal is interesting in view of the fact that in the Cotylosauria, as exemplified by *Pareiasaurus*, we have two foramina for the xiith nerve, and a similar condition is found in the Cynodontia and in the Marsupialia. In the Pelycosauria, as has been shown by Case, and in the Eutheria, there is, as in the Anomodontia, only a single foramen for the xiith nerve.

The canal for the viith nerve lies a little in front of the vestibule. It is long and narrow and passes downwards and slightly outwards, and ends in the small foramen seen at the bottom of the deep groove between the back part of the basisphenoid and the pterygoid.

In front of the specimen is seen the deep pituitary fossa, and below it the carotid canal. The latter begins at a small rounded foramen near the front of the posterior processes of the basisphenoid. The main part of the canal passes upwards, forwards, and slightly inwards, and unites with the canal of the opposite side just in front of the hypophysis. From the lower end of the canal is given off a smaller canal, which passes upwards and somewhat more forwards. While the large canal is pretty certainly that for the carotid artery, the smaller is possibly for the *arteria ophthalmica*. Whatever be the condition of the arteries within the cranial cavity, it must have been very unlike that of *Sphenodon* or other living reptiles, and though perhaps a

little more like the condition in mammals, the resemblance could not have been very close.

The stapes has long been an element which gave rise to difficulties. So far as I am aware, the first author who gave a good figure of the bone was P. Fischer, in 1870, and he regarded the element as the pterygoid. From nearly all the British Museum skulls it has been removed during development, but it still remains and is well shown in the skull which forms the type of *Kistecephalus chelydroides*. Unfortunately, unlike most of Griesbach's work, his figure of this skull in Owen's Catalogue is rather poor, and in the description Owen says nothing about the bone in question. But in any case, as Owen mistakes a portion of the squamosal for the quadrate (his "tympanic"), though the quadrate itself is present in a fairly well-preserved condition, it is manifest that he had not a very clear idea of the structure of this part of the skull. Seeley, when studying the Anomodont skull in 1888, took the massive stapes to be a malleus, and the unquestionably homologous bone in the Cynodonts he later described as possibly a "straight cochlea." Hitherto, I have always looked upon it as the tympanic. Now we know that it is certainly the stapes, though so very unlike the stapes of any living form.

Though a considerable number of Anomodonts are known showing the stapes in position and in perfect condition, I shall describe and figure it and the related bones from the beautiful specimen which I have recently made the type of *Oudenodon kolbei* (Pl. LVI. figs. 4-6). The stapes is here a short dumbbell-shaped bone with the ends flattened and slightly oblique. Across one diagonal it measures 30 mm., across the other 23 mm. The narrowest part of the middle measures 12 mm. across. When viewed from behind the stapes is seen to be much flattened, the narrowest part of the bone measuring only 4 mm. in thickness. A considerable part of the inner end has probably been cartilaginous. The outer end is much flattened and is closely articulated to the inner side of the quadrate. There seems to be no supra- or extra-columella, or if there has been one it must have been relatively very small.

The quadrate, one would readily think, would be the most easy bone in the skull to identify. Many years ago Owen figured what he believed to be the quadrate, and nearly everyone has agreed with his determination. There is a large articulation, about as broad as long. Along its inner third there runs an antero-posterior ridge; near the middle there is an antero-posterior shallow groove; and the outer part of the articulation is a convex disc. This outer part forms the base of a bone which on passing upwards becomes a wide fan-like squamous plate, which is closely applied to the squamosal. If the whole articulation be quadrate this squamous plate must also be quadrate, as has been the view of Owen, Seeley, and myself. It would now appear that about half of the articulation is formed by the quadrato-jugal, and that the squamous plate is also thus quadrato-jugal.

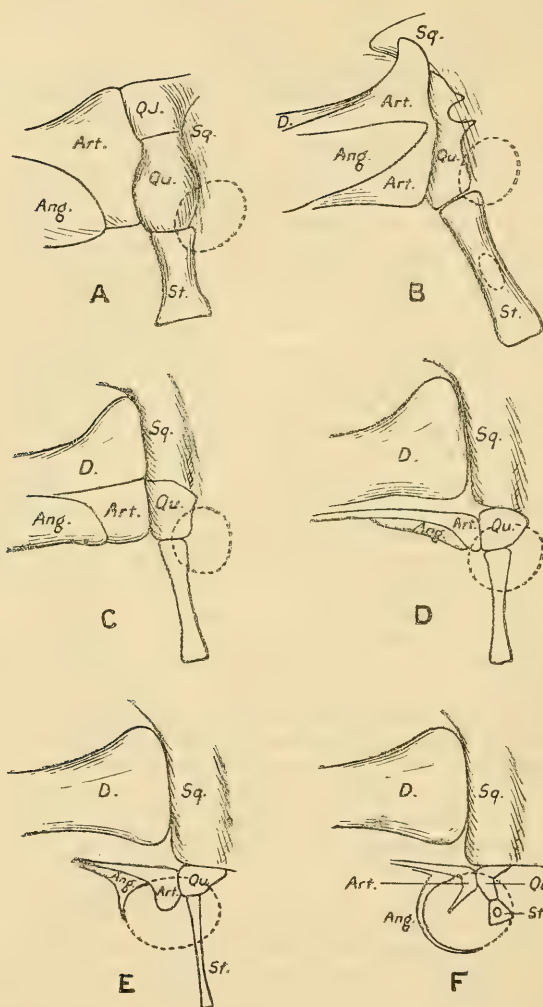
The squamosal comes down behind the quadrate and quadrato-

jugal almost to the articulation. A shallow but distinct groove can be traced down, partly formed by the squamosal and partly by the exoccipital. This is evidently for the external auditory canal, but how the tympanic membrane was attached or whether there was one at all, the evidence does not show. Not improbably there was a membrane attached to the exoccipital, squamosal, and to a small part of the quadrate.

Though the articular region is more perfectly known in the Anomodonts than in other Therapsida, a good deal is known about its condition in the other groups. In the Pelycosaurs the stapes is large and of a peculiar shape, the quadrate is also large and forms the whole of the articulation, and a small quadrato-jugal is present. Little is known of the condition in the Dromasauria. In the Dinocephalia the quadrate is large and forms the whole articulation, and a quadrato-jugal is apparently always present. It is known in *Delphinognathus*, *Moschops*, and *Tapinocephalus*. The stapes is probably very similar to that in the Anomodontia. In the Therocephalia the quadrate is small, but forms the whole articulation. No quadrato-jugal is known in any genus. The stapes is not well known, but appears to be large and long. In the Cynodonts a quadrato-jugal is never present and the quadrate is usually small. In some genera (e. g. *Cynognathus*) a considerable part of the articular surface for the lower jaw is formed by the squamosal, the quadrate forming only about three-fourths of the joint. The stapes in *Bauria* and *Cynognathus* is a fairly strong cylindrical rod: in *Thirachodon* it is also a long rod, but very slender. In all these genera its outer end is firmly attached to the quadrate.

As there are very strong reasons for believing that the mammals are descended from one of the mammal-like reptiles, probably a primitive Cynodont, all the information that can be obtained on the structure of the auditory apparatus is especially welcome, because of the light it may throw on the nature of the mammalian auditory ossicles. And the certain determination of the stapes seems to settle the homologies of the various elements. Had the outer end of the stapes been free and given attachment to a cartilaginous extrastapedial, the dispute might have gone on. But there is apparently no extrastapedial, and certainly the greater part of the outer end of the stapes is firmly fixed to the quadrate. The similar attachment of the stapes to the incus in mammals is striking; and though I have long advocated another view, I now feel forced to agree to the view that the incus is the reptilian quadrate, as advocated so many years ago by Reichert. The slipping out of the quadrate from the joint is not now a very serious difficulty, for in *Cynognathus* we see it already partly slipped out. Nor is there any very great difficulty in understanding how the new dentary-squamosal joint arose. In *Cynognathus*, the posterior end of the dentary nearly takes part in the joint, and there is no difficulty in realising the next stage in the evolution, where the dentary and articular together hinged on the squamosal and the quadrate. As the direct articulation of the dentary on the squamosal became more firmly established, the

Text-fig. 53.



- A. Diagrammatic representation of articulation in *Dicynodon*.
 B. Articulation in the Cynodont, *Cynognathus*.
 C. Hypothetical diagram of the condition when the dentary articulates with the squamosal.
 D. Hypothetical diagram of the condition when the articular and angular no longer support the jaw.
 E. Hypothetical diagram of the condition when the articular and angular take on their auditory function.
 F. Diagram representing the perfecting of the auditory function (the mammalian condition).

quadrate, articular, and angular degenerated, and might have been lost had not the attachment of the stapes to the quadrate compelled them to take on an auditory function.

The tracing of the steps by which the articular became the malleus and how the manubrium was formed is a matter of some difficulty in our ignorance of the position of the tympanic membrane, but we may assume as very probable that soon after the dentary-squamosal joint was formed, the angular and articular rapidly degenerated and ceased to move with the jaw. The tympanic membrane, which possibly in the Cynodonts lay behind the plane of the articulation, probably in the early mammals became shifted more forwards and inwards, and the articular came to support the membrane by the development of the manubrium, while the angular also took part in the support of the membrane and became the tympanic bone. Gaupp is probably correct in regarding the goniale as not the homologue of the angular, but a distinct membrane-bone closely associated with the articular.

In the series of six diagrams given (text-fig. 53, A-F), the probable course of the evolution of the auditory ossicles is shown from the Cynodont type to the type found in the mammal. Though the first figure (A) represents the Anomodont type, this must not be looked upon as on the direct mammalian line, but as a specialised modification of the ancestral type. In fig. B we have represented the Cynodont type as seen in *Cynognathus*. The articulation is formed by the articular hinging on the quadrate and squamosal. The dentary almost reaches the joint. Fig. C represents the probable condition in the later Cynodont type when the dentary came to take part in the articulation. Fig. D represents the later stage when the quadrate has completely slipped out from the joint and the articular and angular have degenerated and no longer move with the dentary. In fig. E we have represented what was the probable condition when the articular and angular first became specialised for their auditory function. This is almost the Monotreme condition. Fig. F represents the condition in the typical higher mammal.

EXPLANATION OF PLATE LVI.

A.S.C. Ascending semicircular canal; *B.O.* Basioccipital; *B.S.* Basisphenoid; *Car.* Carotid artery; *E.O.* Exoccipital; *E.Pt.* Epipterygoid?; *F.O.* Fenestra ovalis; *F.M.* Foramen magnum; *H.S.C.* Horizontal semicircular canal; *Ju.* Jugal; *O.C.* Occipital condyle; *P.S.C.* Posterior semicircular canal; *Pt.* Pterygoid; *Q.J.* Quadrato-jugal; *Qu.* Quadrate; *Sq.* Squamosal; *St.* Stapes; *Ty.M.* Tympanic membrane; *Vest.* Vestibule.

- Fig. 1. Left side of decalcified brain region of small Dicynodont. Nat. size.
2. Right side of partly decalcified brain-region of small Dicynodont. Nat. size.
3. Cast of osseous labyrinth of small Dicynodont, restored from the facts revealed by the two sides. Nat. size.
4. Quadrate region of *Oudenodon kolbei*. Reduced about one half. Front view.
5. Quadrate region of *Oudenodon kolbei*. Reduced about one half. Lower view.
6. Quadrate region of *Oudenodon kolbei*. Reduced about one half. Back view.

24. Zoological Results of the Third Tanganyika Expedition, conducted by Dr. W. A. Cunningham, 1904-1905. Report on some larval and young stages of Prawns from Lake Tanganyika. By Prof. G. O. Sars, C.M.Z.S.

[Received December 5, 1911: Read March 5, 1912.]

(Plates LVII.-LX.*)

INTRODUCTION.

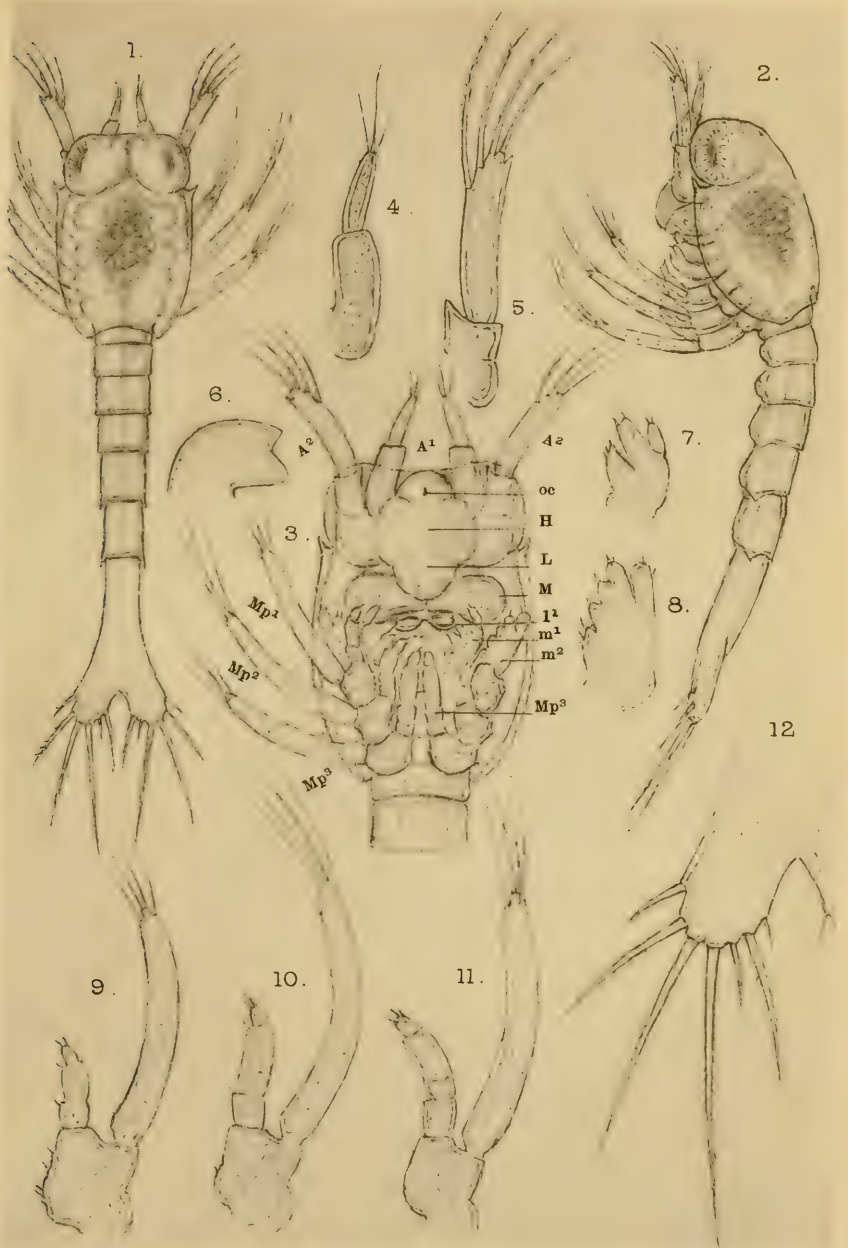
In the tow-nettings taken by Dr. Cunningham during the Third Tanganyika Expedition and placed in my hands for examination of the Copepoda and Ostracoda, some larval and young stages of Prawns were also found. Having submitted these stages to a closer examination, I find that some notes about them may be of interest. We owe to Prof. E. von Daday a rather elaborate account of the postembryonal development of *Caridina nilotica*, var. *gracilipes* (= *C. wyckii* de Man) from Lake Victoria Nyanza, and I have also myself had occasion to examine some larvæ from that lake, occurring in the samples taken by Dr. Cunningham. They agreed on the whole very well with the descriptions and figures given by Prof. Daday. On the other hand, the larvæ found in the samples from Lake Tanganyika have proved to be rather different, apparently owing to the fact that they belong to genera quite different from *Caridina*.

In the present paper I propose to describe three larval forms and one young one, representing as many different stages of development. Two of these forms undoubtedly represent very early larval stages (so-called Zoëæ); but they differ conspicuously both in size and in the development of the appendages, and apparently belong to two quite different kinds of prawns. Of course it is very difficult to decide with any claim of certainty as to the species or even genera to which these larvæ are referable; but I believe that they are in themselves interesting enough to merit a detailed description. They are here simply recorded as Zoëa Nos. 1 and 2, though some suggestions about their probable origin will be set forth. The 3rd form is a larva in the last, so-called *Mysis* stage; and the 4th is a very young prawn in the 1st postlarval stage. Both these forms admit of being more certainly referred to a definite species. At the close of this paper some general remarks will be given.

ZOËA No. 1. (Pl. LVII.)

This larva undoubtedly represents the very first postembryonal stage of some Tanganyika Prawn, having apparently just been hatched. It is remarkable for its small size and the very simple structure of the appendages, being indeed the most primitive

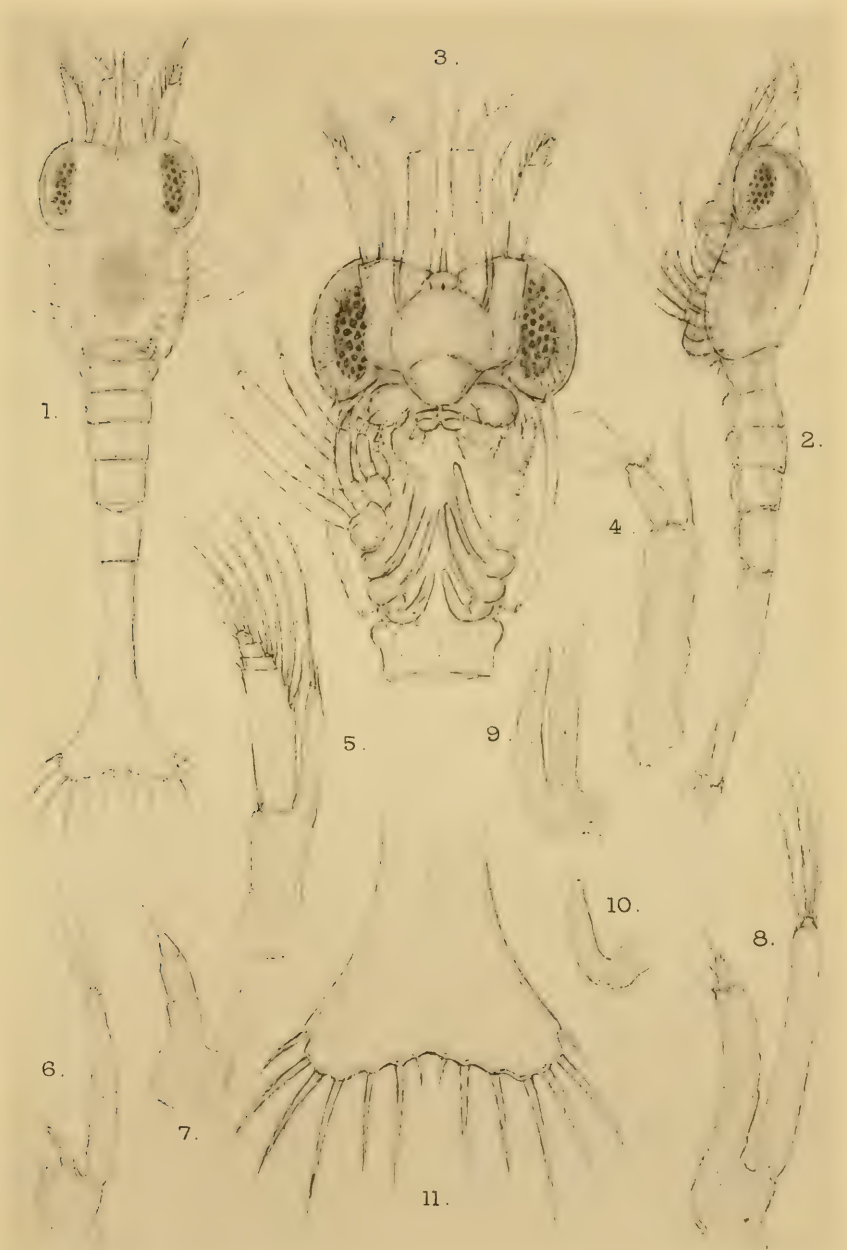
* For explanation of the Plates see pp. 439-440.



G.O. Sars.

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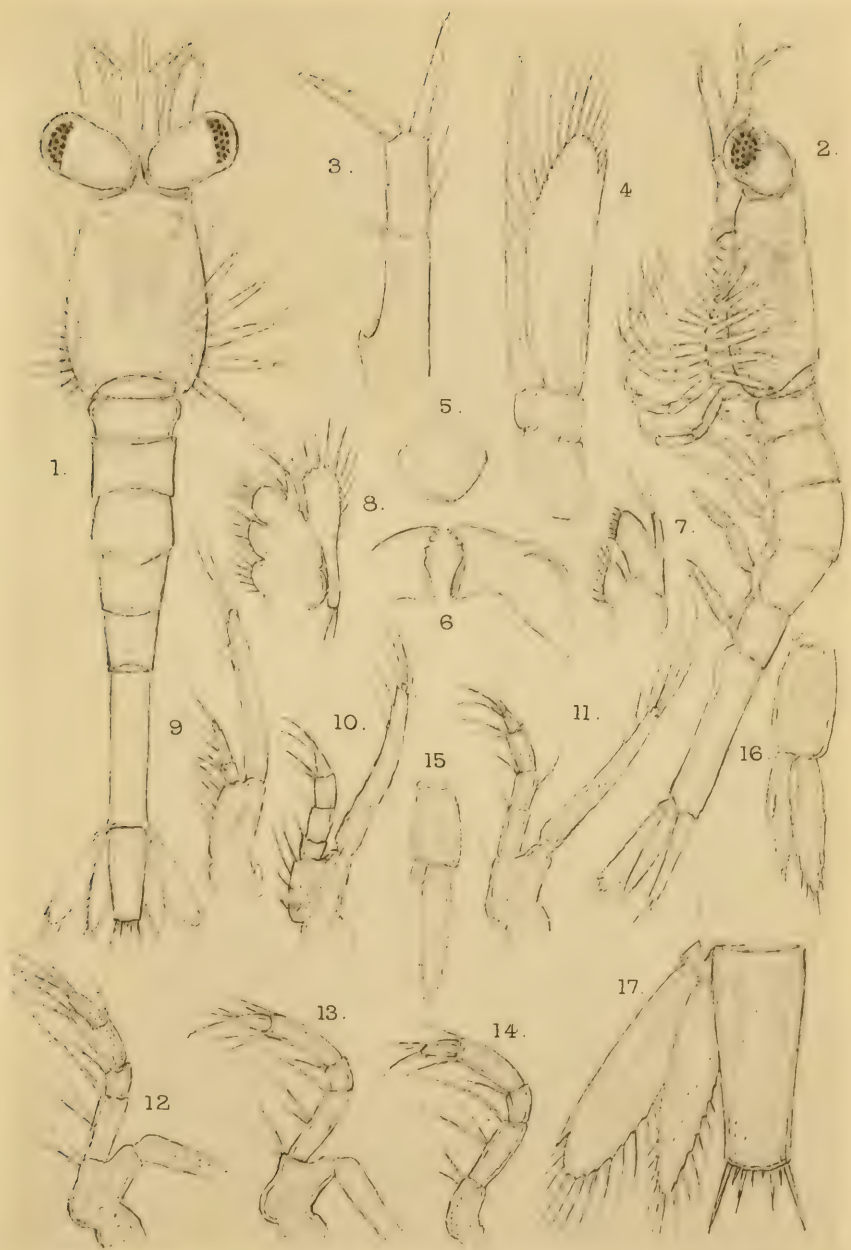
PRAWNS FROM LAKE TANGANYIKA.



G.O. Sars.

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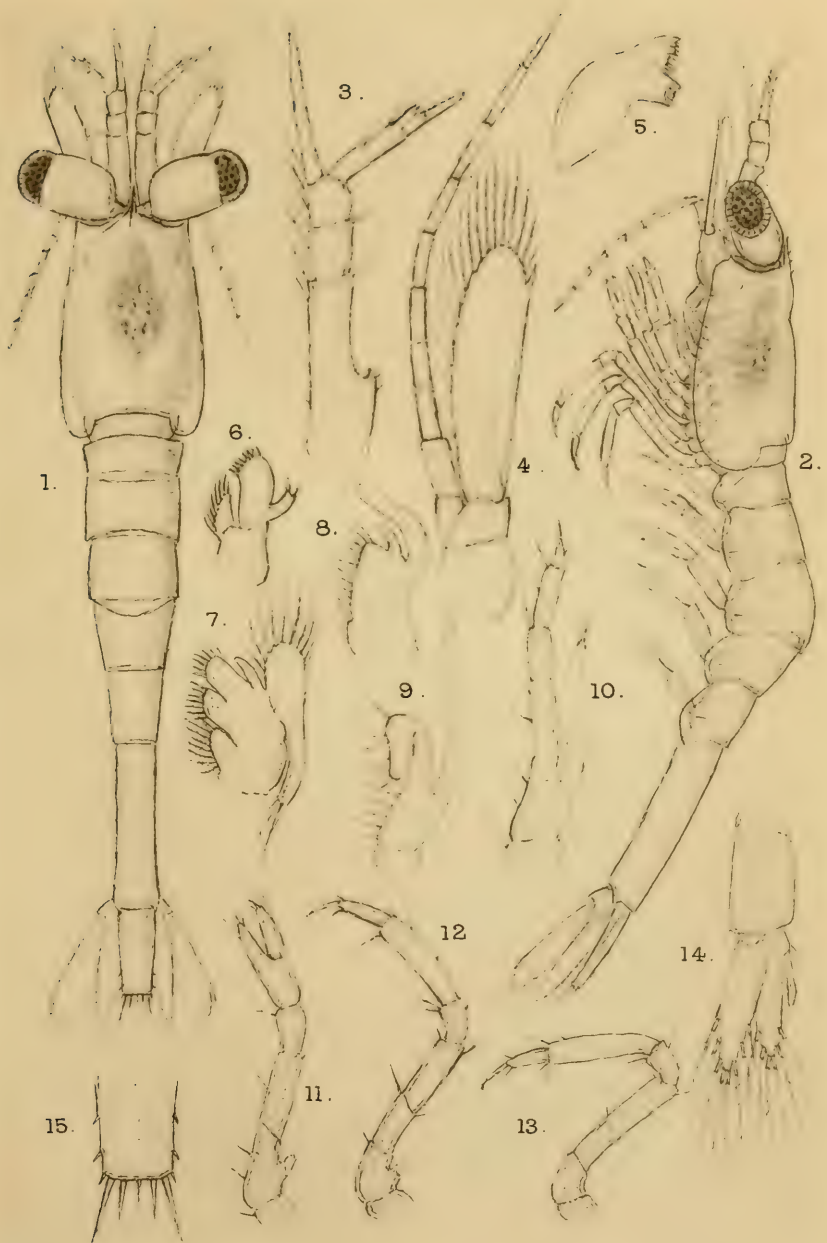
PRAWNS FROM LAKE TANGANYIKA.



G.O. Sars.

London: Printed by C. & J. Clay.

PRAWNS FROM LAKE TANGANYIKA.



Caridean larva that I have ever met with, and in so far is very different from the earliest stage of *Caridina nilotica* described by Prof. Daday under the name of *Kuzoëa*.

The *length* of the specimen examined, measured from the anterior edge of the eyes to the end of the caudal plate, is only 0.70 mm., and the present larva is accordingly not even half as large as the earliest stage of *Caridina nilotica*, the length of which, according to Prof. Daday, is 1.70 mm. If we imagine the larva curled up in its original embryonic attitude, we may approximately determine the length of the ovum from which it has escaped to have been 0.25 mm. by a width of 0.15 mm. This agrees pretty well with the measurements of the ova in *Limnocaridina spinipes* given by Dr. Calman, and as the form of the antennal scale in the present larva agrees better with that in this species than with that in any other of the Tanganyika prawns, I am led to the suggestion that it perhaps might be referable to *L. spinipes*, of which indeed an adult specimen was found in one of the four samples in which the present larvæ occurred.

The *general form* of the body (Pl. LVII. figs. 1 & 2) is moderately slender, with the anterior division somewhat tumid and rounded oval in shape.

The *carapace* is evenly convex above and slightly emarginate behind in the middle, leaving the dorsal part of the hindmost segment of the trunk uncovered. At the antero-lateral corners a well-defined spine is present pointing obliquely outwards (see fig. 1). The anterior part of the carapace is badly defined, and no true rostrum could be detected, though a narrow stripe is seen extending forwards in the middle, without, however, forming any projection in front of the *eyes*. The latter are rather imperfectly developed, as compared with these organs in most other Caridean larvæ. They are apparently quite immobile, being contiguous at the base inside, and do not project beyond the lateral faces of the carapace. The corneal part is only faintly defined and contains a comparatively small and irregular mass of pigment, from which the visual elements radiate in the form of slight stripes, no corneal facets being as yet visible.

Immediately beneath the front parts of the eyes a semilunar lobe occurs (fig. 3, *oc.*), and within this lobe the *simple eye* (ocellus) may be faintly traced, for which reason it is here termed the ocellar lobe.

Of *appendages* only the two pairs of antennæ and the oral parts are as yet present, and all these appendages exhibit a very simple structure, being filled up with indifferent cells. Especially are the mandibles and maxillæ remarkable for their imperfect development, and indeed these parts seem to be quite unfit for any true mastication, the larva in all probability subsisting in this stage exclusively on the nutritive yolk, of which a considerable quantity is seen accumulated within the anterior part of the body.

The relative position of the appendages is best seen on viewing

the animal from the ventral face (fig. 3). The two pairs of antennæ (a^1 & a^2) originate on each side of a median slightly convex area, the hypostome (H), the one pair, the antennulæ (a^1), occurring in front and inside the other pair, the antennæ (a^2). From the hind part of the hypostome the flap-shaped anterior lip (L) is seen to arise covering the inner parts of the mandibles. The latter (M) are easily observed as two comparatively large, transverse, bow-shaped eminences, and immediately behind them in the middle the two rounded lobules of the posterior lip (l) are clearly seen. Behind these parts the two pairs of maxillæ have their place, the 1st pair, or anterior maxillæ (m^1), lying inside and slightly in front of the 2nd (m^2), which are extended obliquely outwards. The maxillæ are followed by three pairs of much larger appendages (mp^1 – mp^3) exhibiting a very similar appearance, each consisting of a short basal part and two diverging unequal rami, the inner one (endopodite) forming a short incurved stem, the outer one (exopodite) a much larger, laterally extended natatory ramus. These three pairs of appendages, which are separated in the middle by a somewhat irregular flattened area (the sternal plastron), represent the maxillipeds in the adult animal. Behind them not even the slightest trace of any pedal buds is to be detected.

The posterior division of the body, or *metasome* (figs. 1 & 2), is rather slender, being about twice as long as the anterior division, and is composed of six well-defined segments, the last of which is much the longest and very narrow. This segment passes without any intervening suture into the caudal plate. The latter is rather unlike that found in most other Caridean larvæ and more resembles in shape that part in the protozoëa stage of *Penæus*. As in that form, it is cleft by a deep median incision into two slightly diverging lobes obtusely rounded at the end. Each lobe carries six finely ciliated setæ of rather unequal length, the outermost one and the innermost but one being considerably smaller than the others. The 4th seta, counted from the outer side, is the longest, equalling in length the last segment to the bottom of the median incision. In some of the larvæ, which otherwise agreed with that here figured, a very small additional seta occurred inside the others on each lobe (fig. 12). On the anterior caudal segments slight traces of the epimeral plates could be detected, those of the 4th and 5th segments terminating in an acute corner. The ventral faces of the segments are somewhat convex; but not the slightest trace of pleopoda is as yet observable.

Structure of the Appendages.

The *antennulæ* (fig. 4) are comparatively small, and each consists of a simple biarticulate stem extended forwards. The proximal joint is much the larger and represents the peduncle. It is, however, quite simple, without any trace of a subdivision and exhibits no armature whatever. The distal joint is much narrower than the proximal one, and also shorter, of oblong-oval

form, and movably articulated to the former. It carries on the tip three or four very delicate bristles, one of which seems to be sensory in character. This joint undoubtedly answers to the outer flagellum in the adult animal. Of the inner flagellum not the slightest trace is to be found in the present larva, whereas in all other larvæ known to me it is at least indicated by a strong seta attached to the inner distal corner of the peduncle.

The *antennæ* (fig. 5), like the antennulæ, are each composed of two sharply defined joints, the proximal of which forms a thickish basal part imperfectly subdivided in the middle, and produced at the end inside to a short conical prominence indicating the place where subsequently the flagellum will be developed. The distal joint, representing the antennal scale, is considerably longer than the basal part and of narrow linear form. Its outer edge is perfectly smooth and terminates in a well-marked tooth-like projection, whereas the inner edge carries in its outermost part four strong ciliated setæ attached to as many well-marked ledges and curved somewhat outwards. In most other Caridea known to me the antennal scale exhibits in the earlier stages of the larval period a rather different structure, its distal part being narrowly produced and divided by well-marked transverse sutures into several successive joints. Of such a subdivision not the slightest trace is found in the present larva, nor is the distal part of the scale produced beyond the tooth of the outer corner, this tooth in other Caridean larvæ being formed only at a much later period.

The *mandibles* (fig. 6) have the inner, or masticatory, part somewhat expanded and divided by a slight median incision into two lobes; but neither of these lobes exhibits the slightest trace of any armature.

The *anterior maxillæ* (fig. 7) are trilobate, with the outermost lobe (palp) well defined as a distinct joint. The middle, or masticatory, lobe is somewhat more prominent than the innermost, or basal lobe. All three lobes extend obliquely inwards and have only very slight traces of marginal spines or setæ.

The *posterior maxillæ* (fig. 8) have the form of oblong oval plates, the edges of which are irregularly indented or divided into a number of rounded lobules. The two outermost of these lobules are separated by a somewhat deeper incision, and represent the one the exopodal, the other the endopodal part, the remaining three lobules of the inner edge representing the true masticatory lobes in the adult animal. As in the anterior maxillæ, only very slight rudiments of setæ are present on the lobules.

The three pairs of *maxillipeds* (figs. 9, 10, & 11), as above stated, are of a very similar structure and only differ in the relative size of the endopodite. The basal part consists of two imperfectly defined segments and is a little broader and more flattened in the 1st pair (fig. 9) than in the other two. The endopodite forms a slightly incurved cylindric stem and gradually increases in length from the 1st to the 3rd pair. In the 1st pair it is

scarcely longer than the basal part and divided only into three joints. In the other two pairs (figs. 10, 11) the middle joint appears faintly subdivided behind the middle. Very small setæ in process of formation are seen on the terminal joint, and partly also on some of the other joints inside. The exopodite, which is movably attached to the outer distal corner of the basal part, is in all three pairs of exactly the same appearance, forming a very flexible, somewhat flattened stem with four long ciliated setæ at the end, two of them issuing from a minute apical joint. In the two posterior pairs another rather small seta is seen issuing inside at some distance from the end.

Occurrence.—Several specimens of this peculiar larva, all closely agreeing both in size and structure, were obtained from four different samples. Two of these samples were taken at Niamkolo (S. end of lake), another at Mbete (likewise at the south end of the lake), and the fourth at Sumbu (S.W. of lake).

ZOËA No. 2. (Pl. LVIII.)

The differences between this and the preceding larva are so conspicuous, that I think we are justified in assuming that it belongs to a different kind of prawn. It is of much larger size, and in some respects exhibits considerably more advanced development. Yet the imperfect structure of the oral parts, in connection with some other features, would seem to prove that it in reality represents a very early larval stage.

The *length* of the specimen examined is about 1.60 mm., and the size of this larva is accordingly more than twice that of the preceding one, and nearly equals that indicated by Prof. Daday for the earliest observed stage (Eu zoëa) of *Caridina nilotica*. The present larva cannot, however, by any means belong to that species, which does not occur in Lake Tanganyika, but must be derived from some other form of prawn, in which the ova are of a similar size to those in the said species. Consulting again the paper of Dr. Calman, we find that in this respect only one of the Tanganyika prawns would seem to come under consideration, viz., *Caridella cunningtoni* Calman, the ova of which are in reality much larger than in any of the other forms examined. I am therefore led to the conclusion that the present larva in all probability may be an early stage of that form.

As compared with the preceding larva, the *body* (Pl. LVIII. figs. 1 & 2) appears rather short and stout, with the anterior division considerably dilated and the posterior one less slender.

The *carapace* is somewhat gibbously vaulted in its anterior part, and, as in the preceding larva, is slightly emarginated behind in the middle. At the antero-lateral corners a well-marked spine occurs; but this spine does not project laterally (fig. 1). Anteriorly the carapace is produced into a well defined, though quite simple narrow spiniform rostrum, which projects distinctly in front.

The *eyes* are of very large size and somewhat project beyond the lateral faces of the carapace (fig. 1). They are, however, like those in the preceding larva, still imperfectly separated in the middle and apparently quite immobile. The corneal part is well defined and contains a semi-oval assemblage of a dark pigment, from which numerous distinctly developed visual elements radiate. The ocellar lobe is partly visible in the dorsal aspect of the animal immediately in front of the eye-bases, but appears more distinctly on viewing the animal from the ventral face.

As to the *appendages*, fig. 3 will give a general view of their form and arrangement in the present larva. On comparing this figure with fig. 3 on Pl. LVII., it is at once seen that both the antennule and the antennæ are considerably larger and also more advanced in development. On the other hand, the oral parts (anterior and posterior lips, mandibles and maxillæ) are very little different. The same is also the case with the three pairs of maxillipeds; but these appendages appear in the present larva more densely crowded and more remote from the hind limit of the mesosome, a considerable space being left behind them, which is occupied by three additional pairs of limbs not found in the preceding larva. These limbs, representing the three anterior pairs of legs are, however, still only in process of formation, being quite immobile and folded beneath the mesosome.

The *metasome* (figs. 1 & 2) is not fully twice as long as the anterior division of the body, and, as in the preceding larva, consists of six segments, the last of which is very narrow in its anterior part, but gradually expands distally, to form the caudal plate. The latter is comparatively smaller than in most other Caridean larvæ, and looks rather different from that in the preceding larva, not being cleft into two lobes, but only slightly emarginated behind in the middle (see also fig. 11). Each half of the plate carries the usual number of marginal setæ, viz. 7, the outermost and innermost ones being rather small, the others nearly equal-sized and comparatively shorter than in the preceding larva. Of uropoda or pleopoda no traces are to be found.

Structure of the Appendages.

The *antennule* (fig. 4) have the peduncle rather prolonged and of cylindrical form, with a slight indication of subdivision into three joints. The outer flagellum, as in the preceding larva, consists of a single oblong oval joint carrying on the lip four unequal bristles, the innermost one distinctly ciliated. The inner flagellum, as in most other Caridean Zoëe, is replaced by a strong ciliated seta attached to the inner distal corner of the peduncle. This seta, however, scarcely exceeds half the length of the peduncle, whereas in the earliest stage of *Caridina nilotica* it is, according to Prof. Daday, nearly twice its length.

The *antennæ* (fig. 5) exhibit the three principal parts well defined. The basal part scarcely differs in structure from that in

the preceding larva; but at its distal inner corner, in place of the simple conical projection found in that larva, a well-defined cylindric stem has been formed representing the flagellum. This stem is about the length of the basal part and exhibits a slight trace of subdivision behind the middle. It terminates in a spiniform process from the base of which a rather long ciliated seta originates. The antennal scale is rather unlike that in the preceding larva, and agrees more in structure with that generally found in Caridean Zoëæ. It exceeds the flagellum by about one quarter of its length and is of narrow oblong form, slightly curved outwards. Its distal part is narrowly produced and divided by well-marked transverse sutures into three successive joints gradually diminishing in size. The scale carries inside and at the tip a regular row of eight ciliated setæ and has, moreover, outside the tip a very small hair-like bristle. Another similar bristle is also seen originating from the outer distal corner of the proximal joint.

The *mandibles* and *maxillæ* do not seem to exhibit any essential difference in their structure from those in the preceding larva, and are scarcely as yet functionally developed.

The three pairs of *maxillipeds* (figs. 6-8) likewise exhibit much the same structure, though the difference in size of the endopodite is still more sharply marked than in the preceding larva, that of the 1st pair (fig. 6) being extremely small as compared with those of the two succeeding pairs, the size of which is also somewhat unlike.

Of the three pairs of imperfectly developed appendages succeeding the maxillipeds the two anterior ones (fig. 9), representing the developing *chelipeds*, are bifid or cleft into two nearly equal digitiform rami, one of which is the endopodite, the other the exopodite. The posterior pair (fig. 10) are still undivided and shorter than the two anterior ones. They represent the first pair of *pereiopoda*, the last two pairs being not yet formed. All these appendages exhibit a very simple structure and are filled up with indifferent cells, no articulation or setous armature being observable.

Occurrence.—Of this larva also several specimens, exactly agreeing with each other, were found. They occurred in two of the samples, the one taken at Niamkolo, the other at Mbete, both located at the south end of the lake.

LARVA No. 3. (Pl. LIX.)

This larva represents a much more advanced stage than the two preceding ones, and therefore can be determined with more certainty. I think that I am right in considering it as the last larval stage, the so-called Mysis-stage, of *Limnocaridina parvula* Calman. The solitary specimen which has come under my notice, was found in a sample which contained several young specimens of that prawn, and both as to size and general

appearance there was a striking resemblance between them and the present form, the larval character of which, however, is at once apparent by the presence of well-developed natatory exopodites on all the legs, except the last pair.

The *length* of the specimen examined was 2.60 mm., measured from the tip of the rostrum to the end of the caudal fan.

The *general form* of the body (Pl. LIX, figs. 1 & 2) is rather slender and exhibits the characteristic Caridean aspect, the metasome being well developed and distinctly bent in the middle.

The *carapace* has the dorsal face somewhat flattened, with a faint cervical sulcus in front of the middle and the posterior edge emarginated dorsally, exposing a part of the last segment of the trunk. At the antero-lateral corners a small spine is seen, somewhat remote from the margin. The rostrum is very small and still quite simple, without any trace of denticles.

The *eyes* are comparatively large and project considerably beyond the lateral faces of the carapace. They are distinctly separated in the middle and freely mobile, being attached to each side of a narrow transverse eminence located just beneath the base of the rostrum. The corneal part is well defined from the thickish pedicles, and has the visual elements very distinct.

The *limbs* of the anterior division are complete in number, five pairs of true legs being present. All these, except the last pair, carry outside natatory exopodites of the same structure as those on the maxillipeds, making in all seven pairs of such appendages.

The *metasome* is more than twice as long as the anterior division and much more powerfully built than in the two preceding larvae. On the five anterior segments the epimeral plates are distinctly developed, though they do not as yet extend beyond the ventral face of the segments. The 3rd segment is more vaulted than the others and has the posterior edge somewhat bowed in the middle, advancing over the base of the succeeding segment. The 6th segment is very narrow, and considerably longer than the two preceding segments combined. It carries at the end a well-developed caudal fan, consisting of a median piece (telson) and two movable lateral appendages (uropoda), each divided into two setiferous lamellæ. The five preceding segments carry each a pair of ventral appendages (pleopoda) exhibiting all the chief parts found in the adult animal, but these appendages seem not yet to have entered into function as swimming organs.

Structure of the Appendages.

The *antennule* (fig. 3) have the peduncle divided into three well-defined joints, the first of which is much the largest and exhibits outside near the base a lamellar expansion terminating in a small anteriorly curving denticle. Some very delicate bristles are seen issuing from the outer distal corner of this and the succeeding joint, and from the inner corner of each of the two outer joints a somewhat stronger plumose seta originates, pointing

straight forwards. Both flagella are distinctly defined and of about equal size. They are, however, still rather short, scarcely exceeding half the length of the peduncle, and do not exhibit any trace of subdivision. At the tip each flagellum carries a bundle of small bristles, and on the outer flagellum, moreover, two bundles of delicate sensory filaments have developed, attached to well-marked ledges of the anterior margin.

On the *antennæ* (fig. 4) the scale is rather large and oblong-oval in form, with the outer edge straight and perfectly smooth, terminating in an acute tooth-like projection. The distal part of the scale is obliquely truncated and projects somewhat beyond the tooth of the outer edge. It is, like the inner slightly convex edge, fringed with a regular row of slender ciliated setæ, about sixteen in number. The flagellum considerably projects beyond the scale and points straight forwards. At its base a short joint has been cut off representing the peduncular part. The terminal part of the flagellum is still quite simple, cylindric, and without any trace of subdivision.

The *mandibles* (fig. 6) have the cutting-edge divided into a number of small denticles, behind which some minute bristles are attached. The molar tubercle may also be distinctly traced.

The *anterior maxillæ* (fig. 7) exhibit a structure nearly agreeing with that found in the adult animal, the middle, or masticatory lobe being rather strong and securiform in shape, with a row of well-developed denticles along the straight inner edge. The very small terminal lobe, representing the palp, is attached outside the masticatory lobe to a well-marked ledge, and carries on the tip three rather slender bristles. The basal lobe is cordiform and fringed with ciliated setæ.

On the *posterior maxillæ* (fig. 8) the exopodal plate is now well defined and mobile, its anterior part being edged with slender finely ciliated setæ, and the posterior part exerted to a narrow lappet carrying on the tip a few setæ. Of the lobes belonging to the endopodal part the outermost one is cut off as a distinct joint, representing the rudimentary palp or endopodite proper; the remaining three lobes are edged with well-developed spines and setæ, and constitute the masticatory part of the maxilla.

The three pairs of *maxillipeds* (figs. 9-11) are less conspicuously transformed, though the 1st pair (fig. 9) by the greater size of the basal part and the considerable reduction of the endopodite somewhat approach the structure of these appendages in the adult animal. The characteristic difference between the two posterior pairs observed in the adult animal is, however, not yet apparent, the endopodite being in both (figs. 10 & 11) of a very similar appearance and agreeing with that found in earlier larval stages, with the only exception that the setæ clothing the joints are more fully developed. The exopodites in all three pairs are unchanged, acting still as natatory organs.

The two anterior pairs of legs, or the *chelipeds* (fig. 12), are of exactly the same structure, the endopodite of both terminating in

a didactylous hand. They are, however, still comparatively short, and do not exhibit the full number of joints, the ischial joint being not yet separated from the meral one. The hand is also imperfect in so far as none of the fingers is as yet mobile. Both fingers are clothed at the obtuse extremity with a few very slender bristles, and similar bristles are also attached inside the other joints. The natatory exopodite is about the length of the endopodite, and of exactly the same structure as in the maxillipeds.

The three succeeding pairs of legs, the *pereiopoda* (figs. 13 & 14), are a little longer than the chelipeds, and have the endopodite of cylindric form and more or less curved, being composed of four well-defined joints. The last joint, or dactylus, is conical in form and carries on the tip a slender spine accompanied by a few bristles. Similar bristles, partly of considerable length, are also attached to the inner side of the other joints. The two anterior pairs (fig. 13) carry well-developed natatory exopodites of the same structure as those on the chelipeds, whereas the last pair (fig. 14) do not exhibit any trace of such appendages.

The *pleopoda* (figs. 15 & 16), as in the adult animal, consist each of a somewhat flattened, oblong quadrangular basal part and two terminal, lanceolate lamellæ, apparently answering to the endopodite and exopodite. These lamellæ, however, still only exhibit very slight traces of marginal setæ in process of formation. On the 1st pair (fig. 15), as in the adult animal, the inner lamella is rudimentary; on the other pairs (fig. 16) it is well developed, though somewhat shorter than the outer one, and carries inside, at some distance from the base, a small digitiform appendage.

The *telson* (fig. 17) has the form of an oblong quadrangular plate, well defined from the last caudal segment, and slightly exceeding half its length. It is armed at the nearly transversely truncated extremity with eight spines of unequal size, the two outermost being much the longest and somewhat diverging, the two innermost and the outermost but one on each side rather small.

The *uropoda* (fig. 17) have the outer plate of a shape very similar to that of the antennal scale; the inner one is a little shorter and lanceolate in form. Both plates are fringed with ciliated setæ and extend somewhat beyond the telson.

Occurrence.—The solitary specimen described above was found in a sample taken at Sumbu (S.W. of lake). In the same sample also occurred a few very young specimens of *Limnocaridina parvula* Calman.

YOUNG PRAWN IN THE 1ST POSTLARVAL STAGE. (Pl. LX.)

There cannot, I think, be any doubt that the specimen described below and figured on the accompanying plate is referable to the same species as the preceding larva, and accordingly is a developing stage of *Limnocaridina parvula* Calman. The similarity in the general aspect is very striking, and the difference in

size is so slight that we have every reason to believe it to represent an immediately succeeding stage. But, whereas in the preceding stage the larval characters were very apparent, they are wholly lost in the present specimen, which accordingly has entered the postlarval period, representing here in all probability the very first stage.

The *length* of the specimen examined measures 2.70 mm., and thus very little exceeds that of the preceding larva. The adult ovigerous female of the present species attains, according to Dr. Calman, a length of 6.70 mm.

The *general form* of the body (figs. 1 & 2) is very slender, even more so than in the preceding stage.

The *carapace* is of a quite similar shape, and the rostrum is very short and spiniform; but on its upper edge three or four small denticles have appeared (fig. 2).

The *eyes* considerably project laterally and exhibit a somewhat fusiform shape, their pedicles being conspicuously dilated in the middle. The corneal part, on the other hand, appears somewhat less expanded than in the preceding stage.

The *metasome* is more powerfully developed, and exhibits the Caridean bend on the middle very distinctly (see fig. 2). The epimeral plates of the five anterior segments are deeper, extending slightly beyond the ventral faces of the segments.

On the *appendages* several changes have taken place, the most conspicuous of which are the complete loss of the natatory exopodites on the legs and the reduction of those attached to the maxillipeds, the natatory function being now wholly transferred to the metasome and more particularly to the pleopoda.

Structure of the Appendages.

The *antennulæ* (fig. 3) have the joints of the peduncle more sharply defined and several additional plumous setæ have appeared inside the joints. The flagella are still rather short, but on both a distinct subdivision has taken place, the inner one being composed of three, the outer of four well-defined joints. On the outer flagellum, moreover, a short uniaarticulate appendicular ramus has developed from the end of the second joint, carrying on the tip a bundle of sensory filaments.

On the *antennæ* (fig. 4) the scale is nearly unaltered, whereas the flagellum has considerably increased in length, being now fully twice as long as the scale. It is, moreover, divided into several joints, the outer of which are very sharply marked off from each other and provided with small hair-like bristles, whereas the proximal ones are still imperfectly defined. The flagellum also appears to be freely mobile in relation to the peduncular part, as it is found in some cases extended forwards, in other cases more or less obliquely backwards (figs. 1 & 2).

The *mandibles* (fig. 5) agree on the whole in their structure with those in the preceding stage, though the molar prominence

appears more distinctly defined and exhibits a well-marked triturating surface.

The *maxillae* (figs. 6 & 7) scarcely differ from those in the preceding stage, except in a somewhat richer supply of marginal spines and setæ.

The *maxillipeds* (figs. 8-10), on the other hand, have been conspicuously transformed, and now look very dissimilar. In the 1st pair (fig. 8) only a slight rudiment of the endopodite is left, and the exopodite also is considerably reduced and apparently quite immobile, without any setæ at the tip, and having the distal part curved downwards. On the 2nd pair of maxillipeds (fig. 9) the endopodite has assumed the characteristic securiform shape observed in the adult animal, the outer two joints forming together a broad plate folded upon the proximal part and armed at the inner edge with a number of spiniform anteriorly curving setæ. On the 3rd pair of maxillipeds (fig. 10) finally the endopodite has preserved its pediform shape, but is considerably prolonged, forming a nearly straight cylindric stem almost twice as long as the exopodite. The latter, as in the preceding pair, is extended straight anteriorly, and appears to be very little mobile.

The *chelipeds* (fig. 11) have increased in length, and now exhibit the full number of joints. On the hand, one of the fingers (dactylus) has been well defined at the base, and connected with the hand by a very mobile articulation; on the tip of each finger a short claw-like spine has developed in addition to the bristles, the number of which is considerably increased. The setæ on the other joints are, however, shorter and less numerous than in the preceding stage. Outside the basal part a very small and irregular protuberance is seen, indicating the place where the exopodite has originally been attached.

The *pereiopoda* (figs. 12 & 13) are somewhat longer than the chelipeds and quite normal in structure. The dactylar joint nearly agrees both in shape and armature with that in the adult animal, as described by Dr. Calman. Outside the basal joint of the two anterior pairs (fig. 12) a minute protuberance quite similar to that occurring in the chelipeds is seen, indicating the original presence of exopodites on these legs. In the last pair (fig. 13) no trace of such a protuberance is to be detected.

Above the bases of the legs, except the last pair, and covered by the lateral parts of the carapace, the *gills* have developed, forming on each side a regular series, as indicated in fig. 2.

The *pleopoda* (fig. 14) are now freely mobile and have the terminal lamellæ fringed with long ciliated setæ. The number of these setæ is, however, as yet very limited, only eight being counted on the outer lamella and six on the inner. All these setæ exhibit close to the base a very conspicuous joint.

The *telson* (fig. 15) does not differ much in shape from that in the preceding stage; but the number of apical spines has diminished, only five such spines being present. On the other hand, three pairs of lateral denticles have appeared, the outer-

most one occupying the outer distal corner, the other two placed at some distance from each other and more dorsally.

The *uropoda* only differ from those of the preceding stage in a somewhat richer supply of marginal setæ.

Occurrence.—The above-described specimen was found in the same sample as the preceding larva, and was associated with three other somewhat larger specimens. Moreover, young specimens of the same species occurred in two other samples, the one taken at Mbete (S. end of lake), the other at Karema (E. shore of lake). In the latter sample numerous specimens were present.

GENERAL REMARKS.

Among the *Macrura* inhabiting fresh water, so far as I know, the genus *Caridina* is the only one in which a true metamorphosis has been found to occur. In the other forms the postembryonal development is either direct, as in *Astacus*, or at least exhibits only very slight traces of a metamorphosis. This difference in the development, according to the medium, may even be found in a single species, viz., in the case of *Palemonetes varians*. The typical form of this species, found in salt or brackish water, passes through a quite normal metamorphosis; whereas in the variety inhabiting purely fresh water the larval development is much abbreviated, the young leaving the egg with all the appendages present, except the uropoda. A similar suppression of the metamorphosis is certainly also observed in some of the marine forms; but these are, as a rule, only such as inhabit very deep water. In shallow-water forms, on the other hand, a complicated metamorphosis is always found to prevail. In most cases the relative size of the ova, borne by the female beneath the metasome, will be suggestive as to the decision whether the metamorphosis in the observed form is complete or suppressed. If the ova are very large and few in number, this is an infallible sign that the metamorphosis is incomplete or quite absent. On the other hand, the presence of very small and numerous ova points to the assumption that the young hatch in an imperfect larval condition, and of course must pass through a more or less complicated metamorphosis before reaching maturity. In most of the prawns inhabiting Lake Tanganyika, as established by the measurements given by Dr. Calman, the ova are of unusually small size, and from this fact alone it could be inferred that a true larval development must be present. This has indeed been fully confirmed by the investigations here published, and in one case it has, moreover, been proved that the larvæ, on escaping from the ova, exhibit a still simpler and more primitive structure than found in any other known form of this group.

A very peculiar feature, exhibited by the two *Zoëæ* described in this paper, remains to be mentioned, viz., the very rudimentary and as it were embryonic appearance of the oral parts (mandibles and maxillæ). In all free marine larvæ belonging to the present

group, even immediately after hatching, I have found that these parts, though more or less differing in structure from those in the adult animal, yet at all events are functionally developed. This cannot, however, by any means be said to be the case in the two Zoëæ here under consideration. On the contrary, it is evident, both from the very imperfect structure of these parts and their position in relation to the mouth, that they cannot possibly act as true masticatory organs. The larvæ, of course, in these early stages are quite unable to feed in the ordinary manner, and must be assumed to subsist exclusively on the nutritive yolk still left within the body. It seems to be very difficult to account for this anomalous case; but a hypothesis may perhaps be set forth. I suggest the possibility that in the lake there is scarcity of that kind of food which would be suitable to the larvæ in this early period, and perhaps also the absolute absence of Cladocera in this lake may be explained in a similar manner. In the more advanced stages, when the oral parts have been more fully developed, the larvæ in all probability feed upon the small Copepoda which abound in the lake.

EXPLANATION OF THE PLATES.

PL. LVII.

Recently hatched larva (Euzoëa) of ? *Limnocaridina spinipes* Clm.

- Fig. 1. Dorsal view of the larva.
 2. Same larva, viewed from left side.
 3. Anterior division of the body, viewed from the ventral face, and more highly magnified. The three posterior limbs on left side are not fully drawn, in order to show those occurring immediately in front of them more distinctly. *A*¹, antennulæ; *A*², antennæ; *oc*, ocellar lobe; *H*, hypostome; *L*, anterior lip; *M*, mandibles; *U*, posterior lip; *m*¹, anterior maxilla; *m*², posterior maxilla; *Mp*¹–*Mp*³, maxillipeds of 1st to 3rd pairs.
 4. Left antennula.
 5. Left antenna.
 6. Inner part of a mandible.
 7. Anterior maxilla.
 8. Posterior maxilla.
 9. Maxilliped of 1st pair.
 10. Maxilliped of 2nd pair.
 11. Maxilliped of 3rd pair.
 12. Left half of caudal plate.

PL. LVIII.

Early larval stage (Zoëa) of ? *Caridella cunningtoni* Clm.

- Fig. 1. Dorsal view of the larva.
 2. Same larva, viewed from left side.
 3. Anterior division of the body, viewed from the ventral face, and more highly magnified. The three maxillipeds on left side are omitted in order to show the maxillæ more distinctly.
 4. Antennula.
 5. Antenna.
 6. Maxilliped of 1st pair.
 7. Maxilliped of 2nd pair (exopodite not fully drawn).
 8. Maxilliped of 3rd pair.
 9. Developing cheliped.
 10. Developing pereopod.
 11. Caudal plate.

PL. LIX.

Last larval stage (*Mysis* stage) of *Limnocaridina parvula* Clm.

- Fig. 1. Dorsal view of the larva.
 2. Same larva, viewed from left side.
 3. Antennula.
 4. Antenna.
 5. Anterior lip.
 6. Right mandible and masticatory part of left.
 7. Anterior maxilla.
 8. Posterior maxilla.
 9. Maxilliped of 1st pair.
 10. Maxilliped of 2nd pair.
 11. Maxilliped of 3rd pair.
 12. Cheliped (exopodite not fully drawn).
 13. Pereiopod of 1st pair (exopodite not fully drawn).
 14. Pereiopod of last pair.
 15. Pleopod of 1st pair.
 16. Pleopod of 2nd pair.
 17. Extremity of last caudal segment, with telson and left uropod; dorsal view.

PL. LX.

First post-larval stage of *Limnocaridina parvula* Clm.

- Fig. 1. Dorsal view of the specimen.
 2. Same specimen, viewed from left side.
 3. Antennula.
 4. Antenna.
 5. Mandible.
 6. Anterior maxilla.
 7. Posterior maxilla.
 8. Maxilliped of 1st pair.
 9. Maxilliped of 2nd pair.
 10. Maxilliped of 3rd pair.
 11. Cheliped.
 12. Pereiopod of 1st pair.
 13. Pereiopod of last pair.
 14. Pleopod.
 15. Outer part of telson.

25. The Classification, Morphology, and Evolution of the Echinoidea Holoctypoida. By HERBERT L. HAWKINS, M.Sc., F.G.S.; Lecturer in Geology, University College, Reading*.

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(Text-figures 54-60.)

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I. INTRODUCTION.

Within the limits of a single class, it would be difficult to find greater contrasts than those which distinguish the various orders

* Communicated by Dr. HENRY WOODWARD, F.R.S., V.P.Z.S.

of the Echinoidea. To a casual observer, unacquainted with the anatomy and embryology of the forms, such genera as *Cidaris* and *Echinocardium* would seem to represent two absolutely different "kinds" of animals. Moreover, search as he might among the Echinoids of the present day, he could find no types that would effectively bridge the gulf that separates the Regular from the Irregular Sea-Urchins. All the Regularia have thick tests, built on a radially symmetrical plan; possess a strong jaw-apparatus; and are armed with stout, often very long, radioles. On the other hand, most of the Irregularia have thin tests, bilaterally symmetrical; have no jaws; and are covered with small, almost hair-like radioles. Even those forms, the "Cake-Urchins," which show a radial symmetry and possess jaws, have other characters which render them very different in appearance from the Regular Echinoids.

And again, from an anatomical study of living forms alone, although a similarity of structure sufficient to warrant their inclusion in the same order of the Echinoderma might be found, no certain clues as to the relation of the two types to one another could be discovered. Even ontogenetic evidence is lacking to a considerable degree, for the peculiar larval life led by Echinoids has tended to neutralise the effect of recapitulation.

At this point, where Zoology in its narrower sense fails, Paleontology can supply the connecting links between such different forms as a Cidarid and a Spatangid; and of these links, the majority are to be found in the group which forms the subject of this research. The order Holoctypoida arose soon after the commencement of the Jurassic period, and became entirely extinct before the close of the Mesozoic era. During its existence it gave rise to forms which, by stages so gradual as to be hardly distinguishable, laid the foundations of all the great groups of Irregular Echinoids that are living to-day. It is the purpose of this paper to indicate in outline the processes through which the specialization of Clypeastroids, Spatangoids, and "Cassidulids" was achieved.

When P. M. Duncan (44)* wrote his classic "Revision of the Genera and great Groups of the Echinoidca," there existed "much diversity of opinion regarding the nature of the perignathic girdles and jaws of some genera" (*i. e.*, p. 135) of the Holoctypoida, the most primitive group of the Irregular Echinoids. As Duncan's system of classification was based to a very large extent on the varying characters of these structures, it naturally resulted that in the case of the Holoctypoida and their allies the grouping of genera into families, or even into larger groups, was somewhat tentative. It is only necessary to remark that jaws are now known to have existed in two genera, in which their presence was denied by Duncan, to show that a revision of the classification of the group is required.

* Where a number in brackets follows the name of an author, the full title of the paper referred to will be found under that number in the chronological list of literature at the end of this paper.

However, the difficulties of a systematic grouping of the primitive gnathostomatous Irregularia are not removed, or even lessened, by the additions that have been made to our knowledge of their comparative anatomy. Rather are they increased, for the establishment of affinities between genera leads to greater complexity of classification than that of differences. The Holoctypoida are an annectant group, the history of whose evolution is so intimately interwoven with that of the early stages of most of the Irregular orders and suborders, that to frame a purely natural classification would need an impracticable plasticity of diagnoses. This systematic trouble is, however, more than compensated by the phylogenetic evidence that it indicates. In the course of the following work I have endeavoured, while recasting the artificial classification of the systematist, to lay emphasis on relationships rather than on contrasts, and to show the position occupied by the Holoctypoida at the foundation of the varied structures of the Irregular Echinoids.

The present essay is the outcome of several years of study of the group, and contains a summary and amplification of a series of papers (see list at end) that have been published in the 'Geological Magazine.' I have thought it unnecessary to repeat here many of the details described in those papers, so that, except where corrections or additions have been possible, the results arrived at in them are taken for granted. There are, however, descriptions of a number of features that find a place here which were not dealt with in the shorter papers given here.

After a brief sketch of the history of the classification of the group, the revised scheme is put forward. This is followed by a morphological comparison of the genera within, and of some genera without, the boundaries of the order; and lastly, the directions of evolution thus indicated are discussed.

II. HISTORY OF PAST CLASSIFICATION.

This part of the paper does not pretend to be a complete account of all the past work that has been done on the group, but it is a summary of the chief systems of classification that have been proposed up to the present time.

The history of the group may be said to date from 1734, when Klein, in his 'Naturalis dispositio Echinodermatum,' distinguished "Sectio I, *Fibula*," from the rest of the "*Echini catocysti circulares*." The section was diagnosed as follows:—"Echinofibulares dicimus *Catocystos* circa Basis circularis peripheriam Anum, Os in medio aperientes." He included two genera only in the section, *Conulus* and *Discoides*, both of which are recognized to-day, and have been associated with one another in most of the systems of classification. Klein apparently did not know of any of the other genera included among the Holoctypoida in the present paper.

The classification adopted in 1840 by L. Agassiz, in his 'Catalogus systematicus,' was in many ways of less value than that of Klein; for he grouped together, under the heading of "Clypeastroidæ," all the non-Spatangid Irregular Echinoids. However, Desor, in the sequel to that Catalogue (11) showed that a more detailed system of subdivision was practicable, and founded the first definite scheme of the classification of the group. The "tribu" of the "Galérîtes" was regarded as a division of the "Clypéastroides." It contained the following genera:—*Caratomus*, *Discoidea*, *Echinoneus*, *Galerites*, *Globator*, *Holcetypus* (as a subgenus of *Discoidea*), *Hyboclypus*, *Nucleopygus*, *Pygaster*, and *Pyrina*. This list of genera contains a very natural grouping of all those Irregular Echinoids which have simple, apetaloid ambulacra. That, however, is almost the only trait that could associate them, and in *Caratomus*, at least, the simplicity of the ambulacra is not absolute.

In the 'Catalogue raisonnée' (1847) Agassiz and Desor retained this grouping of the genera in its entirety, but rearranged the position of the "tribu" as a whole. It appears as the family Echinoneidæ, a section of the Cassidulidæ. This change was at once an advance and a retrogression. It applied to the family a name under which some of the genera have remained since that time, but by associating the whole series with the Cassidulids, it tended to obscure the importance of the gnathostomatous character of many of the genera.

In the Synopsis, Desor (21) retained the division under the name of Galeridées, and added large numbers of genera to the list. He recognized, however, the fundamental importance of the presence of jaws in determining the systematic position of a genus, and so separated the Galeridées into two groups. Of these, the first, or "Galeridées proprement dits," contained fifteen genera with jaws (or rather, supposed to possess them), while the second, the "Echinonées," included *Echinoneus* only. The first group contained all the genera of the "Galérîtes" of 1842, except *Caratomus* and *Echinoneus*, and there were added the then newly described genera *Anorthopygus*, *Asterostoma*, *Desorella*, *Galero-pygus*, *Pachyclypus*, and *Pileus*. It is curious that Desor should have taken it for granted that all these fossil genera were gnathostomatous, for he cannot have had any positive evidence to work upon in the majority of cases.

In 1857 Pictet, in the second edition of his 'Paléontologie' (22), reverted to the method of grouping originated by Desor in 1842, changing the word "Galérîtes" to the subordinal term "Galeritiens," and adding the then recently described *Desoria*.

One year before the appearance of Desor's Synopsis, Wright (20) had grasped the essential differences which divided the "Galérîtes" into two sections. He founded the family of the Echinoconidæ, which contained *Discoidea*, *Echinoconus* (the *Galerites* of most previous authors), *Holcetypus*, *Hyboclypus*, and

Pygaster. He contrasted this family with the Echinoneidæ, in which he placed *Echinoneus*, *Pyrina*, and several other genera. This was the first time that the presence of jaws was treated as an essential feature in the classification of the group.

Wright's system of classification was adopted for many years by almost all the Echinologists who dealt with the group, although slight changes in the generic personnel of the Echinoconidæ were introduced. Cotteau (28) removed *Hyboclypus*, with good reason, from the family, and added the genera (unknown to Wright in 1856) *Anorthopygus* and *Pileus*.

The compact group thus determined, bound together by the characters of a short and accurate diagnosis, became generally accepted. Lovén (31) worked on this classification as a basis, and Wright (32) agreed with Cotteau's modifications. Perhaps no surer indication of the natural character of the grouping could anywhere be found than in the fact that Pomel (37) was unable to find any cause for more than internal changes in the family.

With a subordinal rank within the group of Gnathostomes Clipéiformes, Pomel placed the section Galérides. This section he subdivided into two chief families, the Echinoconidés and the Piléidés. The latter family was further separated into two sub-families, the Discoidiens and the Pygasteriens. Although many new "generic" terms were introduced, no forms were included among the Galérides that were not previously classed with the Echinoconidæ. The separation of the *Echinoconus*-group from the other genera was natural. In the Piléidés, the first group was simply the original genus *Discoidea* of Agassiz in a dismembered state, while the second group included the same author's early conception of the genus *Pygaster*. The classification of Pomel was therefore, in this group, quite orthodox, a condition of affairs sufficiently surprising in view of the great changes he proposed in the arrangement of many of the other groups.

In 1889, Duncan (44), who expressly dissociated himself from Pomel's views of the relative importance in classification of various structures, published the invaluable Revision of the Genera, etc. of Echinoidea. In this work, he realised the great importance of the Holoctypoida as an annectant group. So thoroughly intermediate in its characters was the group that he definitely stated that his classification was artificial, and as such tentative. The Holoctypoida received the rank of an Order, equivalent in importance to the Clypeastroida or the much larger groups of the Diademoida and Spatangoida.

It was chiefly on the peristomial and jaw-structures that Duncan classified the group, and on that account it was particularly unfortunate that he should have had such a fixed belief in the absence of jaws in some genera in which they have since been discovered. Curiously enough, although, in the same year as the publication of the Revision, he definitely stated his disbelief in the existence of jaws in *Discoidea* (45), he allowed that genus to

find a place among the Holoctypoida, while *Echinoconus* was banished to the Echinoneidæ among the Spatangoida. A similar fate befell *Anorthopygus*, while *Conoclypeus*, a genus till then usually classed with either *Echinanthus* or *Clypeaster*, was brought into the Holoctypoid group. (*Conoclypeus* was regarded as a "*Galerites*" by Grateloup, 5.)

Duncan divided the Holoctypoida (whose brief diagnosis was "Exocyclic, oligoporous Ectobranchiata") into two unnamed sections. The subdivision was made on the details of the perignathic girdle, and *Discoidea* and *Conoclypeus*, on account of the supposed rudimentary state of their processes, were thus separated from *Holoctypus* and *Pygaster*. *Galeropygus* and *Pachyclypeus* were regarded as being Holoctypoids, but as not sufficiently known to be definitely associated with, or separated from, any of the other genera.

Duncan's classification was followed absolutely by Sladen in the "Zittel-Eastman" Text Book of Palæontology (53).

The only remaining classification of the group in which any important changes are made is that devised by Gregory in 1896 (50), and published in Lankester's 'Treatise on Zoology.' Here the "Holoctypina" (a group corresponding in part with the Holoctypoida) are regarded as a suborder of the Gnathostomata. The chief contrast between Gregory's group and that of Duncan, is that the former author so modifies the diagnosis of the Holoctypina as to admit *Galerites* (*Echinoconus*), although it is believed to be edentulous. The Holoctypina are divided into four families, the Pygasteridæ, the Discoidiidæ, the Galeritidæ, and the Conoclypeidæ. Discounting the genera described since 1889, the Pygasteridæ correspond to section I. of the Holoctypoida, with the queried inclusion of *Galeropygus* and *Pachyclypeus*. The Discoidiidæ and Conoclypeidæ together contain the members of Duncan's second section, while the Galeritidæ are the first subfamily of the Echinoneidæ of the Revision.

The classification proposed by Gregory seems to accord better with our knowledge than any of those previously suggested. In view of the complexity of the relations of the Holoctypoida, owing to its primitive and annectant character, I prefer to regard it as a group so much apart from the other Irregularia as to merit its retention as an Order, as Duncan originally considered it. After a thorough study of the comparative morphology of most of the genera included in the order, I have attempted to revise its internal classification in such a manner as to indicate the affinities, both internal and external, which the study has made manifest.

III. THE REVISED CLASSIFICATION.

The characters of an annectant group are inevitably plastic and unstable. For this reason a natural classification of such a

group becomes an almost impossible task. The features which seem of essential importance in one genus may be quite absent or profoundly modified in another. But in the case of the Holoctypoida, the length of time during which this plasticity of structure was retained gives possibility for a classification that is fairly in accord with the evolution of the group, and at the same time is free from a confusing multiplicity of detail. However, as will be seen on a comparison of the scheme submitted below with the genealogical table given in a later part of the paper, the two groupings do not agree in every particular. All of the genera have a great phylogenetic significance, and would, if the classification were to do justice to that importance, require each a separate family. Probably, as our knowledge of the relations of the group extends, the present genera will become the bases of distinct families, and will be themselves divided into many smaller sections. The great variety of species which are at present grouped under the generic names *Holoctypus* and *Discoidea* seems to lend support to this belief. For convenience of reference, it has seemed preferable to retain, as far as possible, a more generalized system of grouping than, by comparison with other orders of Echinoidea, the individual peculiarities of the genera in reality demand.

The Holoctypoida are an order intermediate in characters between the Echinoidea Regularia and all the various orders of the Irregularia. The features in their structure which are naturally the most uniform in character are therefore those relics of "Regularity" that they retain. They show a persistently retarded progress in their evolution, and from them, at various points, relatively accelerated offshoots break free. Throughout the entire group two features remain constant in their presence, although they undergo a gradual reduction in the perfection of their development. These features are:—the existence of a masticatory apparatus; and the presence of external peristomial branchiæ. Both of these structures are of essential importance physiologically, and both fortunately leave traces of their existence on the skeletal structures. It is a postulate (which probably expresses a fact) that, whenever the peristome is centrally situated, and at the same time circular in outline, jaws are present. Certainly the existence of a well-developed perignathic girdle indicates their presence, so that, when either of these characters can be observed, the existence of a masticatory apparatus can be inferred, even if it has not been discovered. The branchial incisions on the peristome margin are naturally easy to recognize when that part of the test is preserved.

After the scheme of classification has been summarized, revised diagnoses will be given for the order, families, and genera. Subsequently, the reasons for the exclusion of some genera which have hitherto been classed with the Holoctypoida will be discussed, and their positions in the other orders indicated.

Order **HOLECTYPOIDA**.

Family I. PYGASTERIDÆ.

Subfamily 1. PYGASTERINÆ.

Genus PYGASTER Agassiz.

Subgenus 1. *Pygaster* sens. str.„ 2. *Megapygus*, nom. nov.„ 3. *Macropygus* Cotteau.

Subfamily 2. PILEINÆ.

Genus 1. PILEUS Desor.

„ 2. ANORTHOPYGUS Cotteau.

Family II. DISCOIDIIDÆ.

Subfamily 1. HOLECTYPINÆ.

Genus 1. HOLECTYPUS Desor.

Subgenus 1. *Holectypus* Desor.„ 2. *Cænholectypus* Pomel.„ 3. *Lanieria* Duncan.

Genus 2. COPTODISCUS Cotteau & Gauthier.

Subfamily 2. DISCOIDIINÆ.

Genus DISCOIDEA Agassiz.

Family III. CONULIDÆ.

Genus CONULUS Leske.

Incertæ sedis:—DISCHOLECTYPUS Pomel.

Order **HOLECTYPOIDA** Duncan (emend.).

Euechinoidea Irregularia with external peristomial branchiæ (Ectobranchiata) and a central mouth armed with jaws and surrounded by a perignathic girdle (Gnathostomata).

Ambitus circular, subpentagonal, posteriorly truncated, or slightly elongated. Adapical surface acutely or bluntly conical, apex practically central. Peristome central, usually circular, sometimes decagonal or even obliquely elliptical in outline. Perignathic girdle discontinuous, composed of both processes and ridges. Jaws more like those of the Regularia than of the Clypeastroida. Periproct very variable in size and position, always posterior.

Ambulacra straight, narrow, similar, and simple, with usually larger podial pores on the adapical than on the adoral surface. Towards the peristome the pore-pairs may become grouped into arcs of three. Ambulacral plates small, simple or compound, the latter always derived from three original primary plates. Interambulacra broad; the plates usually concentric in arrangement, rarely bent along their median line. Tubercles always in recognizably vertical series. Apical system variable; madreporite usually large. Radioles short, and longitudinally striated.

Liassic to Uppermost Cretaceous.

Family I. PYGASTERIDÆ.

Holactypoida with a circular or posteriorly truncated ambital outline. Bluntly conical adapically, concave adorally. Peristome large, with strong perignathic processes and feeble ridges. Jaw-structure insufficiently known for diagnosis. Branchial incisions deep. Periproct large, always on the adapical surface, often oblique. Ambulacra slightly tumid, composed of primaries to a point about midway between the ambitus and the peristome. Outer members of pore-pairs often transversely elongated (to a slight degree only) on the adapical surface. Interambulacra broad, paucituberculate (for an Irregular Echinoid), the admedian tubercles being in concentric series, the adradial oblique. Granulation irregular, faintly scrobicular. Apical system with four perforated genital plates; the fifth being usually represented by several small plates. Ocular plates small and similar. No internal buttresses to the test. Radioles short, longitudinally striated.

Liassic to Lower Cretaceous.

Subfamily I. PYGASTERINÆ.

Pygasteridæ with the periproct in contact with the apical system. Ambulacral pore-pairs uniserial except near the peristome.

Genus 1. PYGASTER Agassiz.

With the characters of the subfamily.

Genotype, *P. semisulcatus* Phillips.

Subgenus 1. PYGASTER sens. str. (= *Plesiechinus* Pomel).

Pygaster with the periproct inside, as well as outside, the apical system, and with its greatest width in the adapical part. No posterior genital plate, the remaining plates of the system being arranged transversely. Tubercles with shallow scrobicules, regular in their introduction.

Subgenotype, *P. semisulcatus* Phillips.

Liassic to Middle Oolitic.

Subgenus 2. MEGAPYGUS nov. (*Pygaster* restr. Pomel).

Pygaster with periproct pyriform, and constricted towards the apex. Fifth genital plate present, or replaced by several small plates. Tubercles with shallow scrobicules and irregular in their introduction.

Subgenotype. *M. umbrella* (auctt.).

Middle and Upper Oolitic.

Subgenus 3. MACROPYGUS Cotteau.

Pygaster with the periproct and apical system as in *Megapygus*. Posterior margin strongly truncated. Tubercles with large, deep scrobicules; regular in their introduction.

Subgenotype. *M. truncatus* Agassiz.

Lower Oolitic to Lower Cretaceous.

Subfamily 2. PILEINÆ.

Pygasteridæ with the periproct midway between the apex and the ambitus. Madreporite very large, occupying the centre of the apical system.

Genus 1. PILEUS Desor.

Pileinæ with the ambulacral pore-pairs biserial adapically. Periproct very slightly oblique. Fifth genital plate small, imperforate.

Genotype. *P. pileus* Agassiz.

Corallian.

Genus 2. ANORTHOPYGUS Cotteau.

Pileinæ with the ambulacral pore-pairs uniserial throughout. Periproct markedly oblique. Apical system ethmolsian. Tubercles of interambulacra in sloping lines on both sides of the central series.

Genotype. *A. orbicularis* Grateloup.

Lower and Middle Cretaceous.

Family II. DISCOIDIIDÆ.

Holætypoida with a circular or posteriorly elongated ambital outline. Depressed or elevated, conical, adapically; flat or slightly concave adorally. Peristome of moderate size, with strong perignathic processes and well-developed ridges. Branchial incisions well marked. Periproct of variable size, marginal or adoral in position. Ambulacral plates primaries to the ambitus, compound there and adorally. Pores usually equal and circular. Interambulacra broad, with many vertical rows of tubercles, often supplemented by hypertrophied granules. Granulation usually transversely linear. Tubercles much larger on the adoral than on the adapical surface; arrangement as in

Pygasterinae. Apical system composed of five genital plates, the posterior one perforated or not. Madreporite central. Ocular plates often very small. Radioles short, acuninate, longitudinally striated.

Lower Oolitic to Upper Cretaceous.

Subfamily 1. HOLECTYPINÆ.

Discoidiidae with the periproct marginal or adoral in position. Fifth genital plate smaller than the other four. Tuberculation usually sparse. Perignathic ridges low. No internal buttresses to the test.

Genus 1. HOLECTYPUS Desor.

Holectypinae with the characters of the subfamily.

Genotype. *H. depressus* Leske.

Subgenus 1. HOLECTYPUS sens. str.

Holectypus with the posterior margin often elongated; with a large periproct, marginal or adoral in position. Fifth genital plate small and imperforate. Madreporite central and prominent.

Subgenotype. *H. depressus* Leske.

Lower and Upper Oolitic.

Subgenus 2. CÆNHOLECTYPUS Pomel.

Holectypus with a circular ambitus; periproct of comparatively small size, usually adoral in position. Fifth genital plate almost as large as the others, and perforated.

Subgenotype. *C. macropygus* Desor.

Lower to Upper Cretaceous.

Genus 2. COPTODISCUS Cotteau & Gauthier.

Holectypinae similar to *Cænholectypus*, but with deep excavations along the plate sutures on the adapical surface.

Genotype. *C. næmie* Cott. & Gauth.

Genus 3. LANIERIA Duncan.

Holectypinae similar to *Cænholectypus*, but globular in shape.

Genotype. *L. lanieri* d'Orbigny.

Upper Cretaceous.

Subfamily 2. DISCOIDIINÆ.

Discoidiidae with a circular ambitus; with the periproct on the adoral surface. All five genital plates of approximately equal size, the posterior plate perforated or not. Madreporite often scattered over all five genitals. Perignathic ridges high. Internal buttresses present on the adoral surface.

Genus 1. DISCOIDEA Agassiz.

With the characters of the subfamily.

Genotype. *D. subucula* Leske.

Lower and Upper Cretaceous.

Family III. CONULIDÆ.

Holactypoida with a posteriorly elongated or circular ambital outline. Usually tall and conical adapically; flat or subconvex adorally. Peristome small, slightly elliptical and sometimes oblique, with the perignathic ridges of equal height with the processes, the whole girdle leaning against an internally thickened portion of the adoral surface. Branchial incisions very slight. Periproct small, marginal. Ambulacra of compound plates almost throughout, pore-pairs definitely triserial near the peristome. Interambulacra multituberculate, with both admedian and adradial series sloping adorally, and often in linear sets of three instead of two on each plate. Granulation irregular, granules sunken on the adapical surface. Apical system with four genital plates only. The two posterior oculars meet along the middle line, and are larger than the other three. No internal buttresses, but a marked thickening of the interradian parts of the adoral surface. Radioles similar to those of Discoidiidae; but in addition short ? pedicellaria-stumps arising from the invaginated granules.

Lower to Upper Cretaceous.

Genus 1. CONULUS Leske.

With the characters of the family.

Genotype. *C. albogalerus* Leske.

Lower and Upper Cretaceous.

INCERTÆ SEDIS.

DISCHOLECTYPUS Pomel.

Holactypoida with the characters of *Canholactypus* except in the ambulacra, which are composed of compound plates throughout, as in the Conulidæ.

Genotype. *D. meslei* Gauthier.

Lower Cretaceous.

Discussion of the Systematic Position of Genera formerly included among the Holactypoida, but now removed from the Group.

PLESIECHINUS Pomel.

This genus (or subgenus) included *Pygaster semisulcatus* Phill. and other species related to it. As *P. semisulcatus* is the

type of *Pygaster* Agass. (6), the name *Plesiechinus* cannot be retained. I have, therefore, renamed Pomel's subgenus *Pygaster* sens. str. The "*Pygaster*" of Pomel thus requires a new subgeneric name. As this group, which is typified by *P. umbrellu*, is similar in the character of the periproct to *Macropygus*, and seems to mark a parallel though distinct line of evolution to that subgenus, I have named it *Megapygus*.

PYGASTRIDES Lovén.

As was realised from the first, this small recent form possesses all the essential features of a *Pygaster*, and the species (*P. relictus*) was originally given that generic name by Lovén. There is no direct evidence, so far as I have been able to gather it, whereby this genus should be omitted from the Pygasteridæ. But there is a serious doubt as to its being a "genus," in the strict sense of the word. It is founded on one broken and minute specimen. On first principles, the great lapse of time, unbridged by any similar forms, which separates *P. relictus* from even the latest members of the Holactypoida, renders it improbable that it can be a revived example of the group. Moreover, there has recently come to light some indirect evidence which seems thoroughly to undermine the foundations of the "genus." The presence of a generally *Pygaster*-like facies, and of a complete lantern, in a small recent Echinoid known to belong to the genus *Echinoneus* (Agassiz, 58), in addition to the extraordinary interest of its mere existence, makes it practically certain, to my mind, that the specimen described by Lovén was a similarly atavistic post-larval form. For this reason, I have thought it best to ignore *Pygastrides* in the diagnosis of the Holactypoida, and to omit it altogether from the classification.

GALEROPYGUS Cotteau (Desor).

Several well-marked features render it impossible, as well as unnatural, to associate this genus with the Pygasteridæ. Two striking differences are the strong curvature of the two posterior ambulacra at their adapical extremities (and the extreme narrowness of the areas generally), and the irregularly multituberculate character of the interambulacra. Moreover, the peristome is small, unnotched for branchiæ, and placed anteriorly from the centre. It must be regarded as the earliest known genus of the Nucleolitidæ of Gregory (50), and its affinities will be more fully discussed in Section VI. of the present paper.

ECHINITES Duncan (*Protocyamus* Gregory).

Bather has shown (55) that this "genus" (renamed by Gregory in 1900), being founded on *Discoidea subucula* Leske, must be considered a simple synonym of *Discoidea*. *D. subucula* is the type of the genus.

CONULOPSIS, gen. nov.*

The following is a brief diagnosis :—Ambitus circular, or very slightly elongated posteriorly ; adapical surface conical, not very elevated ; adoral surface flat or slightly concave. Peristome small, slightly excentric, surrounded by interradian "bourrelets." Periproct marginal or inframarginal, transversely expanded. Ambulacra of simple primaries, large adorally ; pores almost subpetaloid adapically. Interambulacra multituberculate, tubercles not in vertical series, deeply scrobiculate, imperforate. Granulation coarse, closely packed.

Genotype. *C. roemeri* d'Orbigny, sub *Galerites*.

Upper Cretaceous.

This genus corresponds with the "*Echinoconus*" of Desor (21), but is certainly not a member of the Holoctypoida. "*Galerites roemeri*" is not a "*Galerites*" at all, but, like the "*Echinoconus abbreviatus*" of our own uppermost Cretaceous (its probable congener), seems to be a near ally of *Caratomus* (see Schlueter, 54), but to be sufficiently distinct to demand a new generic name. A further discussion of the affinities of *Conulopsis* will be found on p. 491.

ADELOPNEUSTES Gauthier.

This genus is founded on one specimen, *A. lamberti*, from the Upper Chalk of Tunis. It is compared by Gauthier (46) with *Galerites roemeri* d'Orbigny, and the comparison, judging by the figures, seems justified. It must therefore follow *Conulopsis* to the *Caratomus*-group.

CONOCLYPEUS Agassiz.

There are two noteworthy features which separate this genus from the Holoctypoida. There are no branchial incisions on the margin of the peristome, and the ambulacra are definitely subpetaloid. Moreover, the interambulacral tubercles are closely packed, without any recognizable vertical arrangement. *Conoclypeus*, and with it probably *Oviclypeus* Dames, represents the most primitive family of the Clypeastroida. The family name of Conoclypeidae used by Gregory (50) may be retained for these two genera.

AMBLYPYGUS Agassiz.

This genus has not, so far as I am aware, been previously associated with the Holoctypoida, but its affinities with that order are at least as well marked as those of the genus last mentioned. It is certainly edentulous, and the tubercles are quite irregularly packed together on the interambulacra. The ambulacra, however, in spite of an appreciably subpetaloid development on the

* A more detailed account of the characters of this genus will be given in a paper that I hope to publish shortly.

adapical surface, have exactly the plating-characters of *Conulus*. *Amblypygus* seems to represent the simplest form of the Tertiary-Recent section of the "Cassidulidæ" (see Hawkins, 66), which is characterized by *Echinolampas* and its allies. The genus will receive fuller consideration in Section VI. of the present paper.

IV. COMPARATIVE MORPHOLOGY.

Throughout this part of the paper references are made chiefly to the structures of the four common British representatives of the group (*Pygaster*, *Holactypus*, *Discoidea*, and *Conulus*). Only when peculiar characters or important contrasts occur in the less abundant or foreign genera is a description of them inserted. I have followed this principle advisedly, because, as this work is largely one of generalization, it seemed preferable to use forms where plenty of material was available, rather than to run the risk of laying too strong an emphasis on a feature which, occurring in an uncommon type, might be an individual peculiarity.

A. The proportions of the Test.

1. *The circumference.*

All the forms which are included in the Holactypoida have typically a radially symmetrical outline around the ambitus. In some of the earlier forms, notably in varieties of *Pygaster semisulcatus*, there is a tendency for the outline to be quite sharply pentagonal by reason of the prominence of the ambulacra, but outside the borders of *Pygaster* sens. lat. this feature rarely appears. It is perhaps worth noting, in this respect, that among the markedly pentagonal forms in my collection of the species just mentioned, there are many of quite small size. Although thus apparently a constant feature throughout life in some individuals, the angularity seems not to represent any phylogenetic stage, but to be merely an irregular, though frequent, variation.

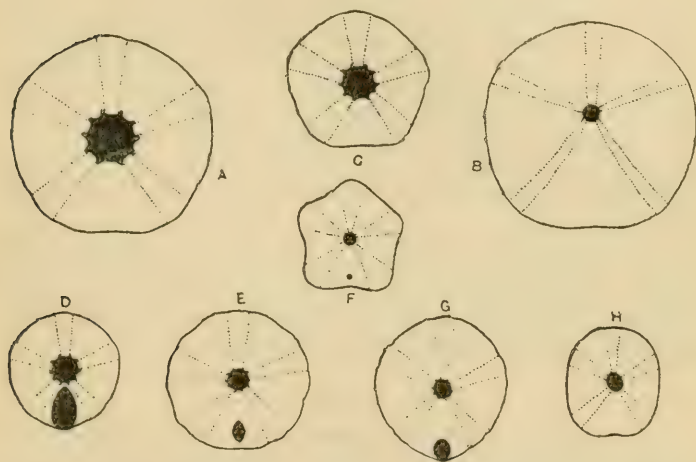
Among the *Pygasters*, when any departure from radial symmetry is encountered, it is found to result from a shortening of the antero-posterior diameter in proportion to the width of the test. This effect is appreciable in *P. (Megapygus) umbrellæ*, but reaches its extreme in *P. (Macropygus) truncatus*. It is in all probability due to an interference with the growth of the plates of the posterior interambulacrum by the great size of the periproct. The truncation of outline is rarely found outside the genus, but in *Desorella* and *Galeropygus* it reappears, often to an increased degree.

The slight groove which, in *P. semisulcatus*, passes from the periproct to the posterior margin, is probably due to the same cause as the shortening of the interradium. It is very interesting and suggestive to find a trace of the sulcus in this genus, in view of the fact that its presence is a notable feature in *Galeropygus*.

and most of the non-Holectypoid Jurassic Irregular genera. A further reference to this feature will be found in the section on the interambulacra (p. 465).

In *Holectypus* there is a tendency opposite to that of *Pygaster*, but one probably caused by the same agent. In such a form as *H. depressus*, where the periproct is of very large size and is situated on the adoral surface, there is frequently a backward projection of the posterior interambulacrum to accommodate it. Even with this projection, there is often but a thin rim of test between the periproct and the peristome—a fact which shows the necessity for some such arrangement. In many of the Jurassic species which have a marginal periproct, a similar tendency is seen (e. g., *Holectypus oblongus* Wright). Although the lengthening of

Text-fig. 54.



Diagrams of the adoral surface in some Holectypoida and their allies showing the shape of the ambitus and characters of the peristome.

- A. *Pygaster semisulcatus*. B. *Galeropygus agariciformis*. C. *Pygaster* (*Macropygus*) *laganoides*. D. *Holectypus depressus*. E. *Discoidea cylindrica*. F. A Clypeastroid. G. *Conulus albogalerus*. H. A cretaceous Echinonoid.

the antero-posterior axis results in a bilateral symmetry comparable with that of many of the Echinoids which are more advanced in "Irregularity," it was not a feature retained by the Holectypoida after Jurassic times. All the species of the subgenus *Cenholectypus*, and all of *Discoidea*, have an approximately circular outline. The slightly indented character of the interradii on the ambitus of *Discoidea* gives an alternating concavity and convexity to the margin which may be compared with that of a *Clypeaster*. In *Conulus* the tendency to elongation reappears, particularly in the large, high-zonal forms of *C. albogalerus*, where the marginal

periproct is often situated on a considerable projection of the posterior interradius. The renewed appearance of bilateral symmetry under these conditions seems to confirm the belief that, so far as the *Holactypoida* are concerned, deviations from radial symmetry are connected with the migrations of the periproct, and depend upon them, having no real significance of their own.

2. *The Adapical Surface.*

With the exception of one rare form (*P. semisulcatus* var. *conoideus*), all the species of *Pygaster* are depressed. The conical shape is not quite regular owing to the interference of the periproct, and the apex is usually a little to the rear of the centre. In *Holactypus* the cone is rarely less elevated than in an average *Pygaster*, and is usually considerably higher. The extreme flatness of *Anorthopygus orbicularis* is quite exceptional for the group. The cylindrical form of *Discoidea cylindrica* is all the more curious because of the normally conical shape of the other and smaller species of the genus. The outline of *Conulus subrotundus* sometimes resembles it, but the vertical character of the sides is never so complete. The Upper Chalk *Conuli* tend, as a rule, to assume an acutely conical shape, so that the area of the adapical is sometimes twice as great as that of the adoral surface. The apex of the test is practically central in all the genera except *Pygaster*.

Among outside genera, almost the only forms to show the sharply conical shape of the *Holactypoida* are *Conoclypeus* and its allies. Most of the Clypeastroids are exceedingly flat in shape, while the bilaterally symmetrical groups naturally cannot be compared with the *Holactypoida* in this feature.

3. *The Adoral Surface.*

There is a very constant progressive change in the form of this region of the test within the group. From *Pygaster*, with a base so concave that specimens placed with the mouth downwards rest on the ambitus alone, to *Conulus*, where the base is to a considerable extent convex, every gradation may be traced. As this feature is directly associated with some of the peristomial characters, it will be better to postpone its discussion to that section of the paper.

B. The Peristome and Associated Structures.

1. *The Peristome.*

The central position of the peristome is constant throughout the group. In its size there is a progressive reduction traceable through the Jurassic to the Cretaceous forms. In *Pygaster* the peristome is of about the same size, relatively to the test diameter, as in an average Diademoid (about one fifth). In *Holactypus* a

reduction is initiated, which is maintained and even accelerated in *Discoidea*, until in *D. cylindrica*, and also in *Conulus*, the peristome has only about one ninth the diameter of the test.

In dealing with this character it is important to realise that the size of the peristome is not of necessity directly connected with the presence or absence of jaws. It is true that in *Galeropygus* and *Pyrina*, where jaws were absent (at least, in adult forms), the peristome is quite small; but in the majority of the Clypeastroids the peristome is smaller in proportion than in these genera, and yet powerful jaws are present.

In the matter of the proportional representation of the ambulacral and interambulacral areas on the peristome margin, a slight but important change occurs in the course of the development of the group. In *Pygaster* sens. str., the proportions are 1 to 1.4 in favour of the interambulacra. In *Conulus* there is no appreciable difference in the share taken by the two areas. This change is partly due to the increased phyllodal tendency of the adoral parts of the ambulacra in *Conulus*, but still more to an actual narrowing of the interambulacra. In view of the extreme reduction which is found in the latter areas of *Clypeaster* and its allies, the progressive change, though slight, is significant.

Apart from the characters of the branchial slits, which will be considered in the next paragraph, the *shape* of the peristome undergoes no important changes until *Conulus* is reached. In that genus the circularity of its outline becomes slightly modified into an elliptical shape, with a tendency for the long axis of the ellipse to be oblique in its relation to the antero-posterior diameter. The departure from the circular form is very insignificant in itself, but when viewed in the light of the persistently elliptical, and usually oblique, peristome of the Echinoneidae, it becomes invested with greater meaning.

2. The Branchial Slits.

All of the genera that I include among the Holoctypoida possessed external branchiae. Within the boundaries of the group, however, it is possible to trace the gradual reduction of these structures (as indicated by the shallowing of the peristomial slits through which they passed) until they become hardly appreciable in size. In no case are there signs of the smooth calcareous developments of the interambulacra, for the support of the gills in a recumbent position, which are characteristic of many of the Regularia Ectobranchiata. The slight modifications of the plate surface that exist are discussed in the section on the interambulacral areas.

In *Pygaster* sens. str., the branchial slits are extremely well marked (in *Megapygus* they are slightly shallower), and the depth of their incision renders the outline of the peristome festooned and decagonal. This stellate shape of the peristome is retained, though to a reduced degree, in *Holoctypus*. In *Discoidea* the slits

are so small that, in spite of the relative minuteness of the peristome, the margin is actually less notched than in *Pygaster*. In *Conulus* the slits are only just distinguishable on the thickened rim of the peristome. In *Pyrina*, and in the Echinoneidæ generally, they seem to be altogether absent.

The concavity of the adoral surface is found to correspond fairly closely with the development of the branchiæ. In *Pygaster*, *Anorthopygus*, and *Holactypus*, the adoral surface is markedly concave, and the peristome is situated in an additional hollow in the centre. In *Discoidea* the surface is almost flat, and yet the peristome is deeply sunken. In *Conulus*, on the other hand, the mouth is practically flush with the test-surface. In the Regular Ectobranchiata the length and stoutness of the radioles are sufficient to keep the test permanently raised above the rock surface. The branchiæ are by this means kept free from the danger of becoming bruised or fouled by contact with the ground. In the Holactypoida the radioles were certainly not so strong as, and probably of far less length than, those of an average Regular Echinoid. As a consequence, the adoral surface would be usually very near to, if not in actual contact with, the rock surface. Such a condition would have a disastrous effect on such delicate organs as the external branchiæ. It seems possible, therefore, that the concavity of the adoral surface of the test is a device for sheltering these structures. In the case of *Discoidea*, where, for purposes of internal consolidation, the lower part of the test is flattened, the region of the peristome is sunk to a proportionately great degree to afford this shelter for the branchiæ. In *Conulus*, where the branchiæ were practically negligible in size, and probably in function also, no such precautions were necessary. For gnathostomatous forms, like the Holactypoida, which were presumably not wholly, or even chiefly, microphagous, this depression of the peristome would appear to be disadvantageous for the capture of food; and only the safety of the equally essential process of respiration could warrant such a development. However, it must be remembered in this connection that the Clypeastroids, in a considerable number of cases, possess a re-entrant peristome without any external branchiæ. They have grooves on the adoral surface converging on the mouth, which may counteract what seems to be an unprofitable structure. Moreover, among them the indentation of the peristome is in all probability connected with the accommodation of the large jaw-apparatus.

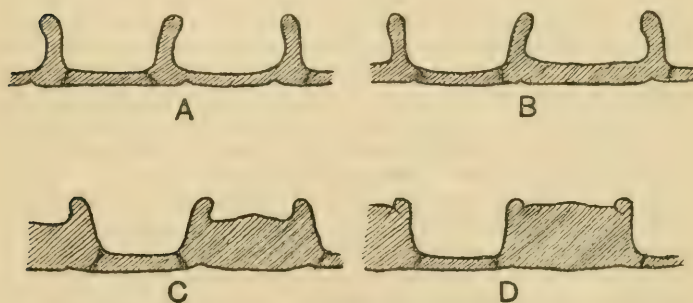
The Holactypoida offer no satisfactory evidence as to the relation between the peristomial and petaloid branchiæ. In the Upper Jurassic *Pygasters* (e. g., *P. (Megapygus) macrocypus*) there is a marked tendency towards petaloid structure in the adapical parts of the ambulacra, but the branchial slits are as well developed as in any of the earlier species. As the genera are traced to the Upper Cretaceous, there is an irregular but frequent tendency seen for the adapical ambulacral pores to become dissimilar, but there is never any contrast sufficient to

warrant a belief that ambulacral branchiae were present. And so in *Conulus*, in the almost complete absence of peristomial gills, there seem to have been no special structures, either left or developed, to perform the function of respiration. In the Echinoneidæ the same condition obtains, but the Clypeastroida show an ever increasing perfection of adapical petals to compensate for the loss of the more primitive adoral branchiae.

3. The Perignathic Girdle.

Detailed and valuable studies of this structure in *Discoidea* and *Conulus* have been made by Duncan and Sladen (40 & 41) and Lovén (43 & 48). These researches have the additional value that they were pursued with different aims. The former authors were intent upon demonstrating the absence of jaws in the two genera, while Lovén predicted, and later realised, their discovery in *Discoidea*. The structure of the perignathic girdles of *Pygaster* and *Holcotypus* is not so fully known, and in the case of *Anorthopygus* there were no known traces of the girdle when Duncan (44) placed the genus in the same family with *Echinoneus*. Lovén (48) knew of its existence in all the three genera, but gave no details of its structure.

Text-fig. 55.



Diagrams of the perignathic girdles in

A. *Pygaster*. B. *Anorthopygus*. C. *Discoidea*. D. *Conulus*.

In *Pygaster* the processes are very strongly developed, while the ridges are hardly recognizable. There is no tendency for the processes to form an arch over the ambulacra—in fact, they slope away from one another. Thus there is initiated the persistently disjunct girdle which characterizes all the gnathostomatous Irregular Echinoids. In *Holcotypus* the structure seems to have been practically the same, but there are indications that the ridges were slightly more pronounced. This was certainly the case in *Anorthopygus*. In *Discoidea* the processes

are proportionately similar to those of *Pygaster*, but their prominence is almost masked by the extreme elevation of the ridges. In *Conulus* this latter feature is carried so far that, except for the suture-line showing that the process is present, the only visible and free portion of the ambulacral part of the girdle is a minute shining knob at each corner of the ridge.

It is, I think, a point of great interest to find that *both* ingredients of the perignathic girdle are so strongly developed in these later Holoctypoid genera. One of the most obvious contrasts between the divisions of the Clypeastroids is the presence in some genera of one support for the jaws in each interradius, and in others of two. It would seem that, when they are double, these supports represent processes, and when single, they are the degenerate relics of ridges. Both such conditions could be obtained readily by the modification of a perignathic girdle in which both portions were equally represented. All that is necessary is a simple process of the elimination of one or the other of the parts.

Another feature of interest in the perignathic girdle of the Holoctypoida, and one connected intimately with the method of use of the jaws, is the angle which the supports make with the plane of the adoral surface of the test. In *Pygaster* the processes are almost, though not quite, at right angles to that surface, with a slight outward slope. This inclination is rather more marked in *Anorthopygus*, and considerably so in *Holoctypus*. In *Discoidea* the angle between the girdle and the floor of the test is quite acute, while in *Conulus* it becomes, especially in thin-tested forms, almost 45 degrees. The practically vertical girdle of *Pygaster* would indicate a correspondingly vertical working of the jaws, similar to that of the Regular Echinoids; while the highly inclined system in *Conulus* seems to show a tendency towards the horizontal working of the jaws of Clypeastroids.

In *Conoclypeus*, according to the description and drawings given by de Loriol (35), the two ambulacral processes are present, but the ridges have dwindled to insignificant proportions, both in width and height. This brings the processes closely together, and there is consequently induced a markedly Clypeastroid appearance in the perignathic girdle.

4. The Jaws.

Our knowledge of the jaws of the various genera of the Holoctypoida is very meagre and unequal. In fact, of the details of the structure of the pyramids and teeth of Jurassic forms next to no evidence is at present available. There are two reasons why this condition of affairs should exist. Firstly, the jaws are internal organs, and so, if they are preserved in the interior of a specimen, it is necessary to break it up before they can be studied. Moreover, it is usual to find the matrix that filtered into the tests of Oolitic forms more compact and refractory in

texture than the surrounding rock. Secondly, the large size of the peristome in the earlier genera would be liable to let the jaw-fragments slip through when their supporting muscles had decayed. As all the species of *Pygaster* and *Holcotypus* are more or less conical in shape, the natural position that the test would assume when allowed to settle on the sea-floor would be with the oral surface downwards. After the jaws had slipped through the peristome they would, on account of their relatively light weight, become scattered by currents which were too gentle to move the whole test.

Jaws are known to exist in *Pygaster*, but I have been unable to find descriptions or specimens in which their structure was adequately shown. From the characters of casts of the pyramids preserved in an ironstone mould of *P. ? semisulcatus* that I have seen, these parts of the lantern seem to have been large and massive, and of a shape corresponding with that of the pyramids of *Cidaris*. Wright (20) has figured a specimen of *Holcotypus depressus* in which the complete lantern is preserved. I have examined the specimen (B.M., E. 1687), but it is impossible to trace any of the ossicles to their extremities, so that no measurements of any value can be taken. The general facies of the pyramid is strikingly "Regular." Nothing seems to be known of the jaws of *Anorthopygus*, but they must certainly have existed.

For a long time the presence of jaws in *Discoidea* was doubted, and sometimes, notably by Duncan (41 & 45), absolutely denied. In 1892, Lovén, in the wonderful store of information as to the perignathic structures of Echinoids contained in his *Echinologica* (Lovén, 48), gave a description of the pyramids in *D. cylindrica*, and recently I was able (Hawkins, 60) to confirm and amplify his description with the additional features of the epiphyses and the teeth. In this genus the pyramids have still a markedly "Regular" appearance, although they were probably much more closely attached to the processes of the perignathic girdle than in any Regular Echinoid. This shortening of the muscles of attachment resulted in a far less vertical position for the lantern as a whole, while the strong incurving of the adoral parts of the pyramids will have increased the angle to one of about 45 degrees at the peristome. The teeth are curved considerably to correspond with this arrangement. They are strong, and built on the Echinoid plan, in contrast to the Diademoid, with a pronounced keel on the concave side.

In the case of *Conulus*, the long controversy as to the presence or absence of jaws has been partly settled by the discovery of teeth in a specimen of *C. subrotundus* (Hawkins, 65). There is as yet no evidence as to the characters of the jaws; and the teeth in themselves, beyond their similarity to those of *Discoidea*, show no features of special interest. They are less curved than those of that genus, and more sharply pointed, the latter character being in contrast to what might be expected in view of the

bluntness of Clypeastroid teeth. The peculiar structures in *C. albogalerus*, usually known as the "buccal plates," are probably in some way derived from jaw-ossicles, as their anomalous character separates them absolutely from the peristomial plates which exist in many other genera. In the paper to which reference has just been made, I have suggested a possible origin and function for the buccal plates, but it must be confessed that the theory advanced there has a very insecure foundation.

So far as is at present known, there is nothing in the structure of the lantern of the Holoctypoida which even foreshadows the curiously expanded pyramids of the Clypeastroida. The probable delicacy of texture of the pyramids in *Conulus subrotundus* may indicate the incoming of a reticulate structure similar to that of the corresponding parts in *Clypeaster*. With regard to the manner of working, the angle of setting of the jaws shows a progressive tendency towards the Clypeastroid method. This retention of the "Regular" facies of jaw-structure throughout the group is rendered the more remarkable by a comparison with the fragmentary pyramids in *Conoclypeus* described by de Loriol (35). That genus, with its Clypeastroid (almost Echinanthine) general build, seems to have possessed the compact pyramids of a *Discoidea*. It is true that the only record of its jaws is very imperfect, but this much seems obvious on a study of de Loriol's drawings. But in *Conoclypeus*, in spite of the Holoctypoid jaw-structure, the perignathic girdle is very like that of *Clypeaster*.

The recently described teeth and lantern in a young specimen of an *Echinoneus* (Agassiz, 58) have a most important bearing on the relation between the Holoctypoida and the Echinoneidæ. The presence of the jaws is undoubtedly a vestigial character, for they seem to be resorbed while the individual is still quite immature. The jaws and teeth both have a *Discoidea*-like appearance, rather than a *Clypeaster*-facies. It is probable that, as they exist in the young stages of *Echinoneus* (the most advanced member of its family), they will have been present in such genera as *Pyrina* at a corresponding stage of development. The likelihood of their discovery in fossil forms is extremely remote, owing to their minute size and delicate texture, but analogy tells strongly in favour of their existence. This discovery is a remarkable instance of the completion by Ontogeny of an unfinished chain of evidence supplied by Palæontology, and removes any doubt which may have existed as to the intimate relationship which links the Conulidæ with the early Echinoneidæ.

In this connection it seems well to suggest the possibility that Lovén's genus *Pygastrides* (Lovén, 43), a "*Pygaster*" lingering so long after the day of the Holoctypoida was past, may be only another example of the vestigial gnathostomatous stage of some, probably Echinoneid, genus. So strongly am I of this opinion, that I have omitted its name from the new classification.

C. The Periproct.

Since the excentric position of the periproct, outside the apical cycles of plates, is a diagnostic feature of the Irregular Echinoids as a whole, it is natural to find that in the Holoctypoida, which includes the most primitive of the "Exocyclic" forms, its position is very variable. When once the periproct has left the apex, its chief tendency seems to be to assume a position as absolutely posterior as possible, and in the course of its passage to such a position, it undergoes many changes itself, and is the cause of many others to the test. It always lies in the posterior interambulacrum.

1. *The Position of the Periproct.*

Practically the only distinguishing feature between a young specimen of a *Pygaster* sens. str. and a primitive Diademoid is the fact that in the former the periproct has broken through the posterior part of the apical system. It cannot be said to lie altogether *outside* the system, for to some extent it occupies the position of the posterior genital plate, and extends well up to the apex of the test. It is, in part, more nearly central in position than in some of the Saleniidae, although its large size causes it to reach away from, as well as into, the apical system.

In *Pygaster* sens. lat., the periproct is always in contact with the apical system,—in the earliest forms reaching to the inner margins of the anterior and antero-lateral genitals, and in the later ones touching only the outer margins of the redeveloped posterior genital. When traced from *Pygaster* sens. str. to *Macropygus*, however, the position of the widest part of the periproct is found to pass gradually backwards, while the posterior edge of the opening approaches the ambitus of the test. *Pygaster*, then, shows a stage in which, although the periproct retains its primitive association with the apical system, the posterior tendency in its position is recognizable.

Pileus and *Anorthopygus* agree in having the periproct entirely on the adapical surface of the test, but quite separated from the apical system. In most cases, however, the posterior part of the periproct is not so near to the ambitus as in *Macropygus*.

In *Holoctypus* we find two groups, as regards the position of the periproct. Both groups appear at almost the same stage of the Lower Oolite, but one is more retarded in character than the other. The former, which may be exemplified by *H. hemisphericus*, has the periproct opening on the margin, that is, in the posterior extremity, of the test. The latter, of which a common representative is *H. depressus*, has the periproct entirely on the adoral surface, and often very close to the peristome. It would appear at first sight that in the former group the periproct had reached the necessary limits of its retrogression, and in the latter had, as it were, overshot the mark. But, in the light of

the later genera, it is impossible to regard the adorally situated periproct of *H. depressus* as a case of overspecialization. Most of the species of *Cœnholectypus* have the periproct in that position, as have all the forms of *Discoidea*. The *H. hemisphaericus* character reappears in *Conulus*, and is retained in most of the Cretaceous species of *Pygrina*.

Text-fig. 56.

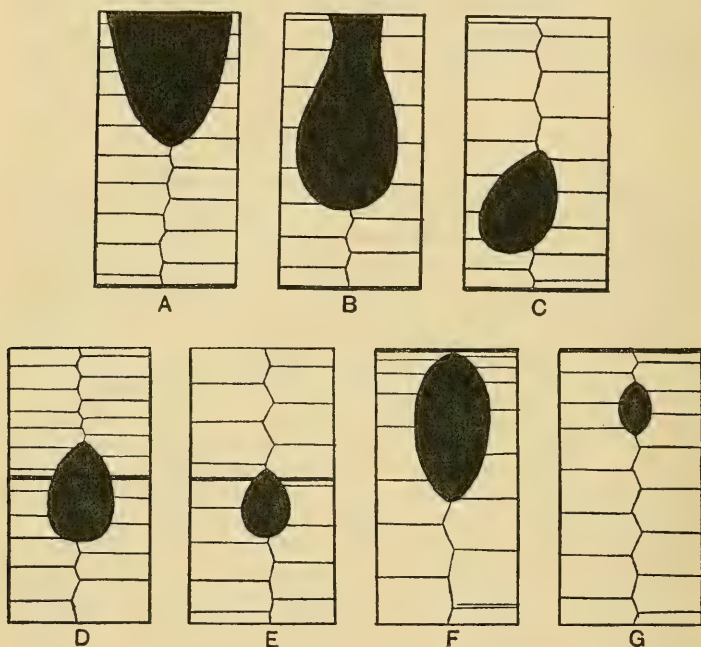


Diagram showing the shape and position of the periproct in A. *Pygaster* sens. str., B. *Megapygus* or *Macropygus*; C. *Anorthopygus*; D. *Holectypus* (*hemisphaericus*); E. *Conulus*; F. *Holectypus* (*depressus*); G. *Discoidea*. The thick line represents the ambitus. The proportionate height of the interradial plates is indicated.

Lovén (36) has indicated the correspondence in periproct-migration that exists between the Holectypoida (his Echinoconidæ) and both the Echinoneidæ and Cassidulidæ. *Galeropygus* and *Clypeus* both have the *Pygaster*-like periproct, in contact with the apical system, while the Nucleolitidæ show an arrangement more like that of *Pileus*. The Echinolampidæ include forms in which the periproct may be marginal or adoral in position.

In connection with the position of the periproct, an interesting feature of the posterior interradius may be discussed. Reference

has been made already (p. 455) to the truncated form of many of the *Pygasters*, and of *Galeropygus*, and the comparatively elongated outline of some *Hiolectypi* and of *Conulus*. The truncation of the posterior interambulacrum is associated with the presence of a more or less defined posterior sulcus; and, in fact, whenever the periproct is on the adapical surface, this sulcus is developed. The functional value of a sulcus below the anus is obvious, as it would tend to restrict the passage of faecal matter to a definite channel, and so to prevent it from coming in contact with the podia. But the developmental meaning of the structure would seem to concern the interference in the growth of the interambulacral plates by the periproct. These plates, formed at the apex and forced downwards towards the ambitus, have to separate along their median sutures to pass round the periproct, and subsequently have to close together below it. The irregularity thus caused results in a retardation of their downward movement (and a consequent shortening of the distance from the apex to the posterior margin of the test), and in a sagging inwards of the reconstructed portions of the plates to form a groove. The probability of this explanation of the structure so characteristic of *Pygaster*, *Galeropygus*, and the Nucleolitidæ, becomes increased when the opposite conditions are considered. When the periproct is marginal or inframarginal in position, the interambulacral plates can pass freely over the adapical surface until the edge of the periproct is reached. Here, in consequence of the lessened width of the divided halves of the area at the sides of the periproct, a delay in the progress of the plates occurs. As a result, the oncoming plates become heaped up against one another above the periproct, and give rise to the elongated, carinate posterior shape which characterizes *Hiolectypus* sens. str., *Conulus*, and also the Spatangoida.

Although it must be admitted that the two opposite conditions, sulcate and carinate, of the posterior interradius have, from a teleological standpoint, an obvious and similar functional value, the explanation given above seems natural in view of their regular association with the position of the periproct. In the case of the Spatangoida, there is the complication of a "posterior surface" to the test, at the upper part of which the periproct is situated. If this surface were curved in conformity with the rest of the test, the periproct would open at a point about midway between the apex and the ambitus, as in *Pileus* or *Anorthopygus*. It seems to me to be a very striking fact that, in the last-named genus, no trace of a posterior sulcus is developed, but that the declivity of the test is appreciably increased as a whole in the region behind the periproct. The Spatangoid posterior surface might, then, be regarded as the product of a retarded growth of the entire posterior interambulacrum owing to the interference of the periproct, while the carina above it would be caused by the same agent in its opposite influence.

In the few cases where absolute circularity of outline is

regained in the Irregular Echinoids, as in *Discoidea* and many Clypeastroida, the periproct is so small as to necessitate very little modification of the steady progress of the coronal plates from the apex to the peristome.

2. *The Shape of the Periproct.*

In *Pygaster* sens. str., the periproct is roughly elliptical in shape, and very large, often having the same width (in transverse measurement) as the apical system. In *Megapygus* and *Macropygus* its outline becomes pyriform, owing to the partial closing in of the interambulacral plates round its adapical extremity. The width never becomes greater than in *Pygaster* sens. str., but the actual size is much larger in these later subgenera, owing to the backward shifting of the posterior edge of the periproct without a corresponding retraction of the adapical margin. The pyriform shape caused by this lagging behind of the upper part of the periproct leaves its impression on the shape of the aperture in later genera. In *Holactypus*, for example, the periproct has its adoral margin rounded, but adapically it tapers to a point. The same feature is seen in *Pileus*. In *Holactypus* sens. str., the periproct is still large; in some species, e. g., *H. depressus*, it is of an extraordinary size. But in *Coenholactypus* it has generally decreased so as to be smaller than the peristome. In *Anorthopygus* the periproct is of moderate size, and has a characteristically oblique position. Obliquity in the case of the peristome is not uncommon among Irregular Echinoids (e. g., *Pyrina* and *Trematopygus*), but this is practically the only form where such asymmetry affects the shape of the periproct to a considerable degree. In this connection it is interesting to find that in *P. (Megapygus) umbrella* the large pyriform periproct shows a distinct inclination towards the left side of the interradius, thus giving an indication of potential obliquity.

In *Discoidea* the periproct is usually lanceolate in outline, often equally pointed at both extremities, but it is always longer than broad. In *Conulus* the marginal periproct is similar in shape to that of *Holactypus hemisphaericus*, although smaller in size. The pointed character of its adapical part is more pronounced in young specimens than in adults. The size and shape of the periproct in the Echinoneidae compares well with those in the Conulidae. In the Clypeastroida the periproct is always adorally situated, as in *Discoidea*, but it is very small, and usually circular in shape.

3. *The Anal Plates.*

The plating of the periproct-membrane is at present unknown in *Pygaster*, *Pileus*, and *Conulus*. In the case of the two genera first named, this is probably due to the large size of the periproct,

and the resulting flexibility of the membrane and weakness of the plating. In the case of *Conulus* (and also of those *Holactypi* which have the periproct marginal), the exposed position of the anal plates on the ambitus may account for their non-preservation. A thickly plated membrane occupies the periproct of *Echinoneus*.

In *Discoidea* the plates of the periproct are not infrequently found *in situ*, and they are known in *Cænholactypus*, *Anorthopygus*, and *Coptodiscus*. The last-named genus differs, as regards this character, from all the others, in possessing a single ring of almost equal-sized plates around the inner margin of the periproct, and in not having, so far as is known, any smaller plates in the immediate surroundings of the anus.

Discoidea has one large anal plate, usually bearing a tubercle, occupying most of the adoral half of the periproct-opening, and a series of fringing plates which decrease in size as they approach the adapical part of the aperture. A few, often only two, small plates occur within this irregular ring, and they are always in contact with the largest plate. The anus is thus situated quite near to the adambital edge of the periproct, in a position far removed from the mouth. In *Cænholactypus*, to judge by a figure of *C. jullieni* from Algiers (Péron & Gauthier, 34), the arrangement was on a similar plan. There, however, the adorally situated plate is relatively small, and the fringing plates are also smaller and more numerous than in *Discoidea*. The inner anal plates are exceedingly minute, and are preserved in considerable numbers.

In *Anorthopygus* I have been able to study only the outlines of the anal plates, these being easily traceable on a siliceous mould of *A. orbicularis* in the British Museum. In this specimen the arrangement of the plating is exactly the reverse of that which obtains in the two genera just described. The largest of the anal plates are adapically situated in the oblique periproct, and a series of pentagonal and hexagonal plates, of approximately equal size, covers all the remaining surface of the aperture except for a very small area in its extreme adoral part. The actual anus, which is represented in the mould by a prominent unsutured portion of the infilling matrix, lies in the true antero-posterior axis of the test, thus being unaffected by the asymmetry of the periproct as a whole. There seems to have been no space occupied by plates between the anus and the periproct margin.

The position of the anus, in its relation to the situation of the periproct on the test, is interesting. When the aperture is on the adoral surface the anus tends to open in its adambital corner, while the same tendency, with an opposite effect, appears when the periproct is supramarginal. A generalization, founded on the somewhat slender evidence of only three generic types, may be made that:—Wherever the periproct may be situated, the anus assumes a position within its borders as near to the ambitus (*i.e.*, the most posterior part of the test) as possible.

D. The Ambulacra.

1. *The Podial Pores.*

Although one of the diagnostic characters of the Holoctypoida consists in the apetaloid nature of the ambulacra, it would be a mistake to assume that the pore-pairs are therefore similar throughout the group. The Nucleolitidæ, which are a group of almost the same antiquity as the Holoctypoida, early developed a marked heteromorphy in the podial pores of the adapical surface; and a similar character, continually recurring, but as often held in check, is apparent among all the Jurassic members of the order. *Pygaster* sens. lat., has uniformly larger pores on the adapical than on the adoral surface, and the members of an individual pore-pair are dissimilar in the former region of the test. Even *Pygaster semisulcatus* sometimes shows this feature. The outer pore of the pair is a little larger than the inner, although both are somewhat elliptical in shape. In *P. (Megapygus) umbrella*, and still more in *M. macrocyphus*, the difference becomes increased. The inner pore is circular, and the outer retains an elliptical shape, often on quite an elongated plan. The long diameter of the outer, elliptical pore never becomes more than twice as great as the diameter of the inner, circular one; so that the whole ambulacrum cannot be said to show even a subpetaloid structure. In *Pygaster*, while this dimorphism of the adapical pore-pairs increases, the size of the pores on the adoral surface steadily decreases. These latter pores are always circular, and the members of each pore-pair are separated by a prominent granule. Their small size renders them quite difficult to distinguish in the Upper Jurassic forms.

In *Holoctypus* a similar tendency is seen, although it is hardly appreciable in the Cretaceous subgenus. The diversity of shape and size in the adapical pore-pairs is rarely carried so far as in *Pygaster*, but the reduction in the diameter of the ambital and adoral pores is quite as well marked. In the case of *Discoidea* the tendency is less noticeable. The pores of the adapical surface are only very slightly larger than those of the adoral (both series being minute), and are themselves always circular. The outer member of a pore-pair is sometimes just distinguishable from the inner one in point of size.

In *Conulus*, by way of contrast, the pores of the ambulacra are everywhere exceedingly minute, those of the adapical surface being even smaller than those of the adoral. The largest pores in this genus are generally situated on or near the ambitus.

Discoidea, and to a further extent *Conulus*, may be regarded as illustrating the triumph of simplicity of ambulacral structure over the persistent tendency to complexity which induced variation in the earlier genera. In the case of *Discoidea*, the simplicity would seem to have been short-lived as soon as its successor, *Conoclypeus*, had emerged from the order Holoctypoida, and initiated the Clypeastroida, where often the petals are developed to a great

degree. As regards *Conulus*, only the Echinoneidæ, among its external relatives, retained the apetaloid character. The Echinolampidæ and the *Conulopsis* group show a pronounced subpetaloid development. Nevertheless, the fact remains that, in the matter of their ambulacral pore-structure, the later genera of the order conform more absolutely to the letter of the diagnosis than the earlier forms.

Text-fig. 57.



Diagram showing some characteristic plates of the ambulacra (from the adapical surface) in A. *Pygaster* sens. str.; B. *Galeropygus*; C. *Megapygus*; D. *Pileus*; E. *Discoidea*; F. *Conoclypeus*; G. *Conulus*; H. *Pyrina*.

The pore-pairs in *Pileus* show an anomalous character in being biserial on the adapical surface, without any corresponding interference with the primary nature of the ambulacral plates. There seems nothing among Irregular Echinoids to compare with such a condition, which recalls the similarly inverted development of biserial pore-pairs in the ambulacra of *Diplopodia*. The somewhat analogous appearance of the pores in the anterior ambulacrum of the Spatangoid *Heteraster* is accompanied by "plate-crushing" in the structure of the area. *Pileus*, in this respect, as in some

others, must be regarded as a curiously specialized offshoot from the *Pygaster*-stock, which only survived a short time, and left no descendants.

2. The Ambulacral Plates.

Recently, in the 'Geological Magazine' (Hawkins, 62), I indicated in outline the principles of ambulacral structure which characterize the Holoctypoida. Later (66) I extended the line of enquiry to the other Jurassic groups of Irregular Echinoids, and showed the influence that plate-structure exerts on the features of the phyllode. It will, therefore, be necessary only to summarize the results of those studies here, for the sake of completeness.

All the Holoctypoida show a crushing together of the primaries to form compound plates in their ambulacra. The degree of crushing is a progressive one. Most of the ambulacrum of a *Pygaster* is composed of primaries, while hardly any unmodified primaries remain in the ambulacrum of a *Conulus*. The building of the compound plates is carried out on a perfectly uniform plan, three original plates going to form one compound plate. The significance of this triple arrangement will be discussed at the beginning of section V. of this paper. *Conulus* differs from all the other genera of the order (except the little-known *Discholectypus*), partly in the early stage at which the crushing commences, and partly in the fact that two out of the three plates concerned retain their primary character (though modified in shape) for a considerable distance beyond the first crushing point, often right down to the ambitus. Two genera may be cited, representing two widely divergent groups, which show an exactly similar ambulacral structure. These are *Pyrina*, of the Echinoideidae, and *Amblypygus*, of the Echinolampidae. It is hard to believe that so peculiar a structure can have been evolved four times independently.

Although there is no true phyllode-structure (nor appearance) developed in the adoral parts of the ambulacra in any of the Holoctypoida, the nature of their plate-crushing inevitably results in a "hypophyllodal" character (see Hawkins, 66) of that region. It is not until *Conulus* is reached, however, that the displacement of the plates drives the pore-pairs into a definitely triserial order. In *Pygaster* the pores hardly deviate from a straight line throughout the length of the ambulacrum, and no regular displacement can be traced in the poriferous zones of *Holoctypus*. In *Discoidea* the pore-pairs become appreciably triserial midway between the ambitus and the peristome, but recover their linear arrangement before the peristome is reached. In *Conulus* a triserial character appears practically at the ambitus, and becomes more pronounced as the ambulacrum is traced towards the mouth; until, near the peristome, the triads are inclined at an angle of 45 degrees to the direction of the radius.

The greatest difficulty that appears when an attempt is made to trace a phylogenetic sequence from the Holoctypoida to the

Clypeastroida is the presence in the latter group of a few large ambulacra in the adoral parts of the area, with no signs of plate-crushing. Can a compound plate be resolved by evolution into its constituent primaries, or is the simplicity of the Clypeastroid ambulacra only apparent, being in reality the result of the fusion of the components of a compound plate, followed by the atrophy of two of the three pore-pairs? Bather (59) has expressed his belief in the possibility of the former process in his discussion of the ambulacra of *Orthopsis*. In support of the alternate suggestion it may be remarked that in the Clypeastroids the pore-pair of each large polygonal ambulacra is situated near the adoral margin of the plate, leaving a high non-poriferous region along the rest of the adradial margin. Moreover, in the case of *Discoidea* just cited, the triserial arrangement of the pore-pairs is arrested soon after its inception, and the poriferous zones again become straight. There seems to be no indication of a corresponding reduction in the degree of compression of the demi-plates towards the peristome, but rather an increase, until the platelets become so minute that the small pore-pair can hardly find room to pass through the test within its borders. The presence of this feature of simplification in the sequence of the pores, but not in the structure of the ambulacral plating, in *Discoidea* seems especially significant; for *Discoidea* is the nearest ally of the Clypeastroids that is found among the Holoctypoida. However, I do not feel justified in expressing a positive opinion, in one or the other direction, upon this question. Much must be done in the study of the postlarval growth of the test in the Clypeastroids before any proof of the origin of their ambulacral structure can be expected.

E. The Interambulacra.

1. The Interambulacral Plates.

The interambulacra are always much broader than the ambulacral areas, and the proportionate width (about 3 : 1 at the ambitus) is retained almost unchanged from *Pygaster* to *Conulus*. Owing to the absence of expanded petals and phyllodes in the ambulacra, there is no compression of the adapical or adoral extremities of the interambulacra such as occurs in most of the Irregular Echinoids. The areas increase regularly in width from the margins of the genital plates to the ambitus, and decrease as regularly, though more rapidly, from the ambitus to the peristome.

In *Holoctypus depressus* there are shallow pits on the transverse sutures at points directly above the branchial slits. I know of no evidence which could ascribe a function to such features. The interradian suture is usually only slightly zigzag in character, and in some forms, notably among the Jurassic *Holoctypus*, it is practically straight, so that the plates become roughly rectangular

in outline instead of being pentagonal. The plates of the adapical surface are generally much broader than high, but on the adoral surface this difference is lessened. In *Holactypus* sens. str., the contrast in the height of the plates of the two surfaces results in the presence of very few interambulacra on the adoral surface. In *Pygaster* the difference is not so strongly marked.

The only member of the group in which any striking difference in the appearance of the interambulacral plates themselves occurs is the peculiar genus *Coptodiscus*. Here, in a form otherwise hardly to be distinguished from *Cænoholactypus*, all the margins of the plates are bevelled, so as to leave deep grooves along the sutures. This feature, which recalls the similar structures in *Goniocidaris* and the Temnopleuridae, is restricted to the adapical surface. Whether it is a result, in this case, of a paucity of carbonate of lime in the water, or of some physiological peculiarity, it is impossible to judge. The feature seems to be quite unique among the Irregular Echinoids.

2. *The Primary Tubercles.*

In their structure and proportions, the primary tubercles show no more variety, when traced through the group, than do the radioles that they support. The equality in size of those of the adapical and adoral surfaces, which is marked in *Pygaster*, becomes gradually replaced by a tendency towards an increase in size of the adoral tubercles, with a corresponding decrease of those of the adapical surface. In *Discoidea*, especially in *D. subuculus*, the reduction of the adapical tubercles has proceeded so far that they can hardly be distinguished in size from their attendant miliaries. Apart from a tendency in *Conulus* for the boss to become wholly convex in side view, and so fill the scrobicule more completely than do the partly concave sides of the boss in *Pygaster*, there are no changes of importance to be traced in the actual structure of the tubercles.

In the arrangement of the tuberculation more variation is found, and there becomes manifest a continual tendency towards a progressive increase in its complexity. I have dealt with this character (Hawkins, 67) in considerable detail, and give here a summary of the results obtained in my recent paper.

As Saemann and Dollfuss (27) showed, the actual number of tubercles present on each interambulacral plate depends largely on the size, that is, on the age, of the individual. In all the Holactypoida there is at least one plate, at each end of the half interradius, which supports a single tubercle. This is obviously a relic of the primitive, unituberculate character of the plates of the earlier Regular Echinoids. The number of such plates remaining decreases steadily as the group is traced from the Lower Jurassic to the Upper Cretaceous. The median series of tubercles persists in an unbroken line from the apex to the peristome, but, except in *Pygaster*, is not readily distinguishable

from its associates in point of size. Each tubercle in this median series is placed slightly nearer the adoral than the adapical transverse margin of the plate. All the other tubercles, of which

Text-fig. 58.

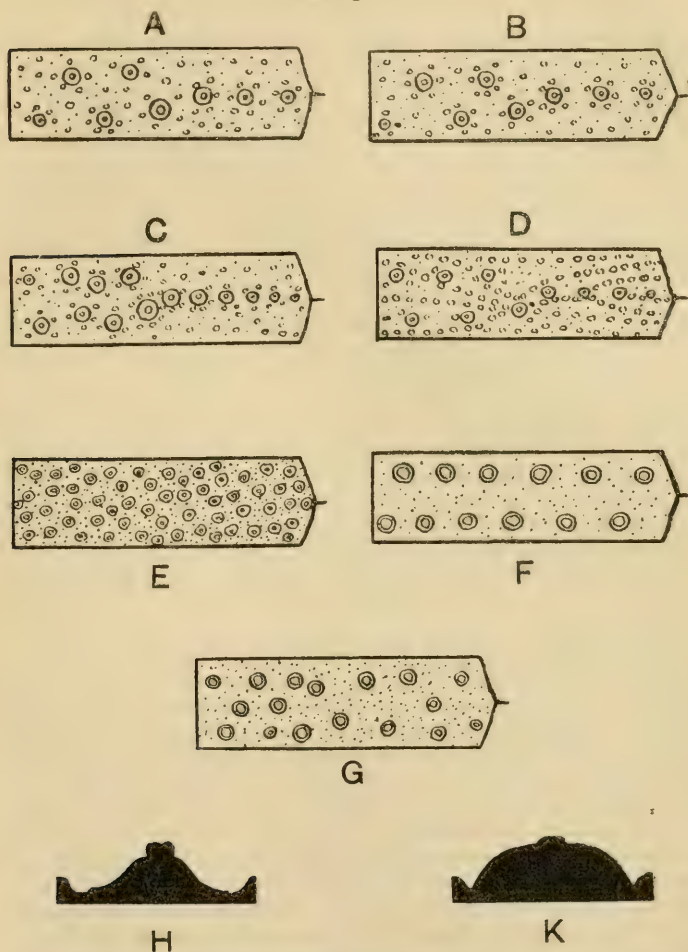


Diagram showing the third plate above the ambitus in A. *Pygaster* sens. str.; B. *Holectypus* (*hemisphaericus*); C. *Holectypus* (*depressus*); D. *Discoidea*; E. *Galeropygus*; F. *Anorthopygus*; G. *Conulus*. Figs. H & K are side views of primary tubercles in *Pygaster* and *Conulus* respectively.

great numbers may occur in the later genera, are developed in recognizably vertical series. When their number becomes great, a natural tendency to slight irregularity appears, but this is never

sufficient to mask the plan of the tuberculation. Irregularity generally consists of either the suppression of a member of a series on one plate (a feature often seen, even in the primary row, in *Echinus*), or its replacement by two tubercles. The Holoctypoida are peculiar among Irregular Echinoids in retaining throughout life the unituberculate plates and the vertical arrangement of the tubercles. Only the Echinoneidæ show any similar plan, and in them it is very much obscured by irregularity of development. Some forms of *Pygurus* (e.g., *P. blumenbachii*) have one or more unituberculate plates at the adapical extremities of their interambulacra, but this retardation of development is obviously due to the considerable narrowing of the plates caused by the expansion of the ambulacral petals. However, most, if not all, of the Irregular Echinoids whose post-larval development has been studied, show a unituberculate stage. This is notably the case in *Echinolampas* (see Agassiz, 30).

The tubercles of the additional series which develop on the interradianal tracts are at first situated each in the middle line (in a vertical sense) of the plates. This results in a transverse line of tubercles extending between the main series and the interradianal suture. The concentric arrangement thus caused characterizes *Pygaster* sens. lat., *Holoctypus* sens. lat., and *Discoideu*. It seems somewhat irregular in the case of *Pileus*, and is definitely absent in *Anorthopygus* and *Conulus*. In these two genera the tubercle series of the interradianal tracts appear near to the adapical and adoral margins of the plates alternately, thus giving an oblique arrangement (sloping interradianally and adorally) to the tubercles in the complete interambulacrum. A similar arrangement to this affects the adradial tubercle-series in all the genera of the group.

The oblique setting of the tubercles results in a much more uniform and packed tuberculation over the whole area than exists when the interradianal series are transverse. The closeness of the arrangement is increased by the doubling of many of the tubercles in *Conulus*; so that, instead of two tubercles, three or even four are concerned in the composition of the oblique line on each plate. The complexity of arrangement, coupled with a homogeneity of character, of the tubercles, which was thus slowly obtained during the course of evolution of the Holoctypoida, was rapidly developed, and carried to a further degree, by the earliest of the non-Holoctypoid Echinoids. The species of *Galeropygus* from the Lias show typically the bewildering profusion of small tubercles which characterize the interambulacra of all the Nucleolitidæ, "Cassidulidæ," Clypeastroida, and early Spatangidæ. Only the Echinoneidæ seem to preserve a *Conulus*-character in their tuberculation, and in them it becomes so irregular as to be hardly appreciable except in the newest formed plates.

The peculiar sunken supernumerary tubercle of some of the adapical interambulacrals of *Holoctypus depressus* from the Cornbrash recently described (Hawkins, 67) is without a parallel

among the other members of the order. Although suggesting a comparison with the large interpetalous interambulacral tubercles of such a genus as *Eupatagus*, it seems to be a specific character of no genetic value.

3. The Miliary Granules.

In *Pygaster*, and to a less degree in *Holactypus*, the granulation shows a "Regular" affinity in being grouped around the primary tubercles to form scrobicular rings. This circular arrangement is not retained after the Jurassic period. In *Holactypus*, especially in *H. depressus*, the scrobicular miliaries on the adradial tracts of the plates near the peristome are often guttate in form. In *Macropygus* and *Anorthopygus* the large size of the scrobicules of the primary tubercles leaves little room for miliaries, but those which exist do not appreciably group themselves around the primaries. In *Discoidea* and *Conholactypus*, and to a slight degree in *Holactypus* sens. str., rows of granules radiate from the central primary tubercle, maintaining a more or less transverse direction, to reach the adradial and interradian margins of the plate. In the genus first named these linear rows of granules become interspersed, near the ambitus, with additional tubercles.

In *Conulus* the granulation is apparently without a definite system of arrangement. The granules are sunk slightly below the level of the test on the adapical surface, being enclosed in minute pits. On the adoral surface they regain their projecting character, and often occupy broad bands, slightly elevated, which correspond in position with the transverse sutures of the plates.

F. The Radioles.

Our knowledge of the acanthology of the Holactypoids is fragmentary and inadequate. Enough is known, however, to show that there exists a considerable uniformity in the character of the radioles throughout the group. Wright (20) has described the primary radioles of *Pygaster*, in the species *semisulcatus* and (*Macropygus*) *morrisii*. For both he uses almost the same words—short, needle-shaped bodies with fine longitudinal lines on the stem. I have not seen any specimens in which they are preserved. In the case of *Holactypus* there is a specimen of *H. depressus* (from the Inferior Oolite of Cheltenham) in my collection which retains a considerable number of radioles on both the adapical and adoral surfaces. Wright (*t. c.*) describes them in the same species. The primaries of the upper surface are very short and slender, with blunt tips. Those of the adoral surface were apparently quite long, and but slightly tapering. The collars of the adoral radioles are prominent, and often very oblique. The shafts of both sets of radioles are longitudinally fluted with closely-set ribs. The miliary granules support spines of a similar character to the adoral primaries, but far more minute, so that Wright's description of them as "hair-like" is accurate.

I have been unable to find any record of the preservation of radioles in *Discoidea*. In *Conulus* the primaries are very much like those of the adoral surface of *Holactypus* in shape and ornament. The miliaries support curiously blunt prominences, which are usually preserved *in situ*, but are very easily rubbed off by too vigorous development of the specimen. These blunt spines were figured by Forbes (14), who also gave a drawing of a curious body that he regarded as a pedicellaria. The characters of the miliary spines suggest a comparison with the calcareous supports of pedicellariæ; but if they all had this function, the number of those organs would be extraordinarily great in proportion to the radioles.

Nothing seems to be known as yet of the microstructure of the radioles of any genera of the group, as Hesse (51) did not choose an *Holactypoid* for his researches.

The slight progressive change traceable in the primary radioles seems to lead merely to an increase in the length, and perhaps in the slenderness, of their shafts; while, as would be expected from the difference in size of the tubercles on the two surfaces of the test, the adoral radioles become proportionately longer than those of the adapical surface.

G. Internal Buttresses.

The difference in form which makes so violent a contrast between a *Scutella* and an *Echinus* must result in a corresponding difference of resisting power against the pressure of the waves. As both types of Echinoid may live between tide-marks, where the violence of the waves is most felt, they both have the same forces to repel. A spherical body such as that of an *Echinus*, or even a hemispherical one, like that of an *Holactypus*, could easily ward off the blow of a breaking wave, in the same manner as a *Patella* does. But a flat test, such as that of a Scutellid, would offer a blank resistance to the waves, and, if hollow, would almost certainly be crushed. For this reason, the few groups of the Irregular Echinoids that frequent the exposed littoral habitat so characteristically occupied by the Regular forms, strengthen the resisting power of their tests by the development of massive calcareous buttresses within. Practically the only Irregular forms which live openly on the shore at the present day are the Clypeastroida. It becomes, therefore, a point of especial interest to find the beginnings of internal supports to the test among the *Holactypoida*, which is the only other gnathostomatous (and therefore rock-dwelling) order. Although the development of the buttresses in the two groups might easily be regarded as an illustration of similar adaptation to similar environment alone, yet, in the light of the other less obviously utilitarian features of the two groups, it seems in this case that a genetic explanation exists as well.

On the internal mould of a *Pygaster*, and yet more in one of a *Pileus*, besides the deep pits left by the prominences of the

perignathic girdle on the adoral surface, there are grooves (representing ridges in the test) that pass from the processes alongside the ambulacra (but situated on the interambulacra) for a short distance. The structure might be regarded as indicating a gradual rise of the inner surface of the test to form a keel which culminates in the perignathic process. As, among Regular Echinoids, the perignathic girdle rises quite abruptly from the inner surface, this gradual rise of the test towards the processes shows a new feature, the beginning of the inner buttressing of the test.

In *Holactypus*, as the name implies, a diagnostic feature of the genus as first tentatively suggested by Desor (11) is the absence of grooves in the internal moulds. This of course means the absence of internal ridges passing radially outwards to a point beyond the ambitus. An investigation of some siliceous moulds of *H. ? sarthacensis* has shown me that, although there is nothing in the interambulacra to compare with the strong "cloisons" of the succeeding genus, there nevertheless exists a considerable thickening of the adoral regions of those areas, even more than in *Pygaster*. In *Discoidea* the first signs of a really efficient internal buttressing appear. Down a line, rather to the adradial side of each half-interradius, there passes a thickening of the test which is rounded near the peristome and becomes carinate further out, and which extends beyond the ambitus. The partitions do not pass for any considerable distance up the adapical surface. The perignathic girdle tends to lean against the adoral ends of the supports.

In *Comulus* no such well-marked buttresses appear, but the interambulacral areas undergo a great amount of thickening towards the peristome. Indeed, the perignathic girdle, which is itself well developed, is often less internally elevated than the interambulacral plates against which it reclines. The ambulacra pass in sunken grooves across the adoral surface. In one specimen, on cutting a section through the interambulacrum at a point just outside the perignathic girdle, I found a large hollow to be included between an inner and an outer wall of calcite. I have not been able to verify the occurrence of this feature in other sections. It may, therefore, have been an abnormality or the result of an accident; but if it should be found to be a general tendency, or even one of fairly frequent occurrence, it would be very significant in the comparisons that might be drawn between it and the double flooring of the test of many of the higher Clypeastroida.

It is only in *Discoidea* that the buttresses are in such a freely projecting condition that they could be expected, by a growth in their height and an accompanying depression of the adapical surface, to form complete vertical partitions in the test. As it is, these "cloisons" of *Discoidea* are rather more strongly developed than the corresponding structures of *Echinocyamus*, which otherwise they resemble very closely. In fact, Gregory (50), in renaming the "genus" called *Echinites* by Duncan (44), which included only

the species *Discoidea subucula*, used the name *Protocyamus* "to indicate the affinity of this Echinoid with the *Echinocyamus* series." The name, on systematic grounds, must be abandoned, but its significance remains.

In *Conulus*, but, so far as I am aware, in that genus only, a definite "sand-canal," similar to that of *Echinocorys* and the Spatangidae, is well developed on the inner surface of the madreporic genital. In the same genus, in adult specimens, a double row of hemispherical prominences occurs, partly encircling the inner part of the test a little above the ambitus. Klinghardt (68) has recently discussed the relation of these thickenings to the course of the alimentary canal, for the mesenteries of which they seem to have given attachment. He has compared the course of the gut thus indicated with that of several fossil and recent species of Spatangidae. In the present state of our knowledge, however, but little of importance can be ascertained of the comparative anatomy of the soft parts of fossil Echinoids.

H. The Apical System.

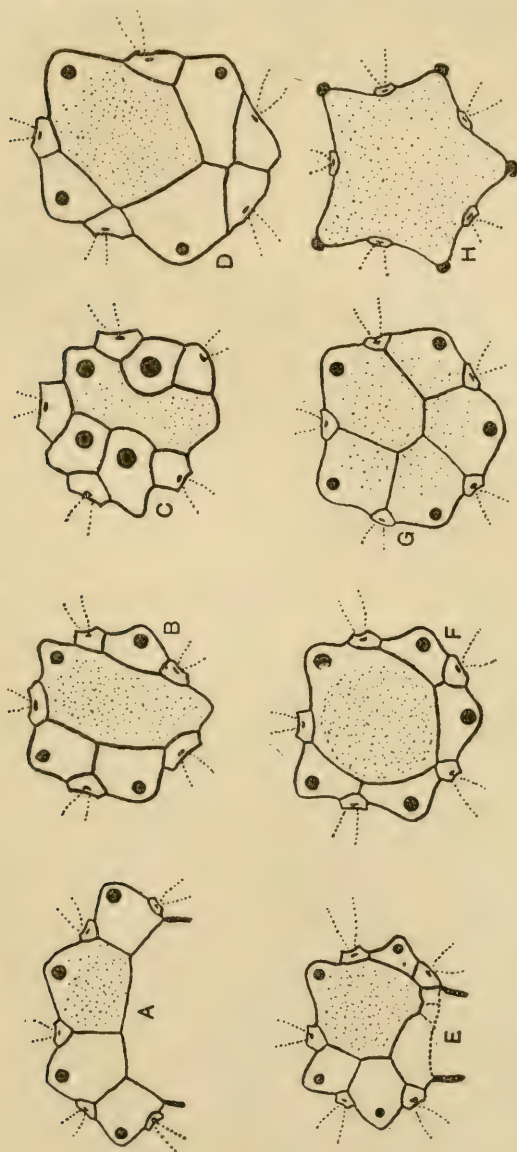
Much of the systematic work that has been done on the Irregular Echinoids has had as its basis the character of the apical system. Notable cases where this feature has been utilized for the purposes of classification are the works of Gaudry ('Enchaînement du Monde animal') and Pomel. From a purely morphological standpoint the system has been carefully described by Lovén (31). In the case of the Holoctypoida, and of some of the near allies of that group, I have recently summarized the state of our knowledge of the apical system (Hawkins, 70) in a paper that was definitely a preliminary note to the present work. In consequence, only the comparative aspect of the subject need be dealt with here, and for the description of details that paper may be consulted.

The apical system is at first thoroughly disorganized in its composition and structure by the passage of the periproct through its cycle of plates. In *Pygaster* sens. str., the first stage of disruption is still visible. The posterior genital plate is entirely absent, and the remaining four genitals are grouped in a roughly semicircular order around the anterior edge of the periproct. The madreporic genital is not much larger than the other three. The oculars are small, and show no features of special importance. From a broken and open condition such as that shown by *Pygaster* sens. str., the processes of evolution work along two definite directions. The first aims at a restoration of a cyclic, or at least of a compact, character in the system as a whole, and the second is concerned with the infilling of the centre of the system (when the cycle is regained) to replace the absent periproct.

In the reconstruction of the cycle of genital plates, the posterior (fifth) genital is not necessarily resuscitated. In fact, a very large number of the great groups of the Irregular Echinoids are permanently without this plate. *Anorthopygus* shows the simplest

condition of the cycle-restoration on this plan. In that genus the postero-lateral genitals close in, so as to bring the system to an

Text-fig. 59.



The apical system of some Holotrypoids and their allies. (Reduced to a common size, but correct in proportion.)
 A. *Spatangus* sens. str. B. *Anorthopagus*. C. *Spatangus*. D. *Conulus*. E. *Pygaster* (*Megapigus*). F. *Cenoholotypus*.
 G. *Discoidea* (the posterior genital pore not invariable). H. *Clypeaster*.

approximately circular shape, and the place of the posterior plate is taken by a prolongation of the madreporic genital through the

system. This great increase in the size and extent of the right anterior genital achieves two results. Firstly, the interior of the apical system is filled by it (with the madreporite), and secondly, the posterior margin of the system is completed by its extension. The resulting structure is an apical system of the ethmolysian type (see Gregory, 50). The great importance of this character in *Anorthopygus* becomes evident when it is realized that such a system is found only in it and in a section of the Spatangidæ. It may be stated at once that the method of infilling of the centre of the system shown in this genus is characteristic of all those Holoctypoida in which the apical plates regain a genuinely cyclic arrangement.

The second method whereby the system is rendered compact, without the redevelopment of the posterior genital plate, is shown by *Conulus*. Here the two posterior oculars become greatly increased in size, and meet along the posterior margin of the system. The postero-lateral genitals undergo a similar transverse extension to a greater or less degree, and meet above them. The madreporic genital, although large and partly occupying the centre, is in this way separated from the posterior region of the system. A slight antero-posterior lengthening of the whole system usually accompanies this method of development, and, in a simple sequence indicated in my recent paper, the markedly elongate apical systems of a *Pyrina* and a *Holaster* can be readily derived. The *Conulus*-plan is characteristic of the apical systems of many Jurassic Nucleolitidæ, although it is not the only type developed in that complex series of forms.

Of the type of apical system in which the fifth genital is redeveloped (or perhaps replaced by a new but similar plate), *Pygaster* (*Megapygus*) shows the first stage. Here one small plate, perhaps more, imperforate and in all probability flexibly united to the others, makes its appearance at the adapical extremity of the periproct. It seems probable that this new genital plate is a specialized member of the anal series which has become incorporated into the apical system. In *Megapygus* it is always small and imperforate. The next stage in recovery is seen in *Holoctypus* sens. str. In this genus the fifth genital is present as a recognizable unit of the genital cycle. It is always smaller than its four associates, however; and of these, the madreporic genital is very large, occupying all the central part of the system. The posterior genital is still imperforate. In the succeeding series of forms (*Cænholectypus*) the relations of the genital plates are similar to those in the earlier subgenus; but a genital pore, quite as large as those of the other plates, passes through the posterior genital. *Cænholectypus* shows, then, the perfect restoration of the apical system. All five genital glands will have been functional, each with a separate pore; while the centre of the apical system is filled by the madreporite, situated, as usual, entirely on the right anterior genital plate.

The apical system of *Discoidea* is particularly interesting. The

fifth genital becomes practically indistinguishable, in point of size, from the others of the cycle, even the right anterior plate being much reduced from its condition in *Holactypus*. The posterior plate may or may not be perforated, this irregularity affording in itself ample proof of the plastic condition (in a variational sense) of the genus. The madreporite, instead of being restricted to the right anterior genital, is more or less uniformly distributed over all five of these plates in some species, a feature never found in the preceding genera. (In the case of an otherwise abnormal *Conulus albogalerus*, a similar development exists: see Hawkins, 70.) The oculars have dwindled considerably in proportional size.

The chief interest of this peculiar structure is seen when a comparison is made between the apical systems of *Discoidea* and *Clypeaster*. In the latter genus the madreporite is central and prominent, but it is quite impossible to distinguish the sutures of the genital plates, at least in adult forms. The oculars are minute. *Discoidea*, then, shows the preliminary stages of the assimilation of the genitals—a phenomenon that is preparatory to their coalescence and fusion in the Clypeastroida.

V. THE INTERNAL EVOLUTION OF THE ORDER.

1. Features of Phylogenetic Importance.

In palæontological attempts to trace a phylogenetic sequence through any series of organisms, the first and essential feature to be considered is the order in time in which the various forms appear. Most of the serious errors that have marred the value of some past work in this direction have resulted from an insufficient reliance on the stratigraphical relations of the genera considered. It is true that our knowledge of the occurrence of fossils at various horizons is very inadequate: it is only necessary to consider the number of cases where a gap exists in the sequence of forms that are known to occur in widely separated horizons, to realize this incompleteness of our knowledge. But it seems a fair postulate to assume that the order in which various genera make their appearance is approximately the true sequence of their evolution. Especially is this the case in the Holactypoida. Not only are they, in common with most Echinoidea, eminently adapted for preservation in suitable deposits, but the periods of their existence, the Jurassic and the Cretaceous, were times when, at least in this country, the conditions of deposition were exceptionally favourable for the preservation of organic remains. In the scheme of evolution put forward below, no apparent relationship has been accepted unless the stratigraphical evidence confirmed it.

A second great principle from which reliable evidence of genetic affinity can be deduced is that of Ontogeny. Here, unfortunately, our knowledge of the Holactypoida is meagre. In the Echinoidea generally the process of recapitulation is always very much obscured

by the existence of a free-swimming larval stage. Of post-larval changes in the Class but little is known. Agassiz (30), in the Revision, summarized the state of knowledge of the "young stages of *Echini*," and but little has been added since that date, at least in the case of the Irregularia. Ontogenetic characters are always difficult to observe and to appreciate among fossil forms, and far more zonal collecting of young stages of the Jurassic and Cretaceous Echinoids will be necessary before this line of evidence can be used for their correlation.

Some slight details are available at present, such as the *Hemipedina*-phase of *Pygaster semisulcatus* and the young stages of *Conulus* with an adapical periproct. (Valette, 69, has described a young specimen of *C. subconicus* in which the periproct is already in the adult position, although the individual has a diameter of only 10 mm.). Unlike the Mollusca and Brachiopoda, the Echinoidea do not retain the first-formed portions of the test throughout life; so that, although new parts are continually being developed, the acceleration by which these new portions assume adult characters almost nullifies any recapitulatory features they may possess. In the matter of the interambulacral tuberculation, which at first seems a promising structure for ontogenetic study, this feature of acceleration renders the characters of the new plates practically worthless.

In addition to their sequence in time, it is therefore necessary to consider the adult characters of each genus separately. The features of an adult are divisible into two kinds. The first group is that of adaptation to circumstances; and the characters due to this tendency, though interesting from other standpoints, have little phylogenetic meaning. The second group of characters are those which are unaffected, or are not necessarily affected, by the surroundings of the organism, and which must in consequence owe any peculiarities they possess to the line of evolution of the group to which the individual belongs. Such features, which include atavistic and vestigial structures, are of first-rate importance for showing the phylogeny of a group. In the Echinoidea, the characters that would fall into the first category would be those directly concerned with assimilation, respiration, reproduction, and locomotion. The characters of the second type would consist of apparently trifling variations in the ornament or structure of the test—variations of such a kind as not to affect the vital processes to any serious degree, nor be affected by them. Such characters are the details of the plating of the ambulacra and the variations, within certain limits, in the structure of the apical system. These two characters are regarded as essential indices of relationship in the present paper.

There is, however, in the investigation of an extinct, annectant group like the Holoctypoida, an additional principle of evolution that gives safe guidance. The two extremes of structure—those of a Cidarid and of a Spatangid—are known. Generally speaking, the Holoctypoida should show a gradual tendency, in the course

of their evolution, to depart from the characters of a Cidarid, and to approximate to those of the Irregular types. A recognition of this *direction of evolution* in the group renders the interpretation of the various structures more intelligible by including them all in one coherent scheme. A complete reliance on this principle would probably result in a misinterpretation of degenerate or retarded development, so that the trend of evolution must be considered in direct connection with stratigraphical evidence.

To sum up, the characters used here as indices of phylogenetic development are of two kinds. One series is available for tracing the evolution of the group as a whole. Such features are (i.) the gradual loss of masticatory structures and of peristomial branchiæ, (ii.) the backward movement of the periproct, (iii.) the loss of radial symmetry, and (iv.) the increase in density, and decrease in coarseness, of the tuberculation. The other series is used to indicate the intimate relations of the individual genera of the group. These features are (i.) the plating structure of the ambulacral areas, (ii.) the composition of the apical system, and (iii.) the stratigraphical sequence.

2. The Origin of the Group.

The oldest known member of the Holoctypoida is *Pygaster reynesi*, which occurs in the Middle Lias of France. It will therefore be necessary to look for the ancestor of this typically Holoctypoid form among the Regular Echinoids of the Liassic or Triassic periods. It is unfortunate that the origin of the group should date from these periods, for, unlike the purer waters of the Oolitic seas, the muddy shore-lines of the Liassic ocean, and the saturated lagoons of the Triassic coral-reefs, were unfavourable to the free development, as well as to the ultimate preservation, of Echinoids. However, it is significant to find that the earliest Irregular Echinoid appeared so soon after the first stage of differentiation had begun among the Regular orders. Its inception thus seems to have been an effect of that unrest in structure and habit that usually accompanies profound changes in the course of the evolution of a Class.

The Liassic Regular Echinoidea seem to belong to two orders only, the Cidaroida and the Diademoida. The former group had become more or less stereotyped in character during the Permian and Triassic periods, having been, as Bather (59) indicates, the only surviving member of the varied Palæozoic types. The Diademoida, as the same author has shown (*t. c.*), were beginning to assume the typical features of the order in Triassic times, but still retained features, such as a primary character of the ambulacral plates in the greater part of the area, and a shallowness of the branchial clefts, which are reminiscent of their Cidaroid ancestry.

From the Lias a considerable number of primitive Diademoida are known, and they have been recently studied by Lambert (52),

Tornquist (57), and Bather (59). A great part of their ambulacra is still built of primaries, which show no signs of their subsequent modification except in the arrangement of the primary tubercles, one to each group of three ambulacra. A large number of these Liassic forms are grouped under the generic names of *Diademopsis* and *Hemipedina*. These genera and their Diademoid allies have been so exhaustively studied by Bather (*t. c.*) that no detailed discussion of their characters or affinities is necessary here. One of the most obvious features which separate these early Diademoids from their descendants is the structure of the perignathic girdle. The processes, although well developed, are rendered quite inconspicuous by the considerable elevation of the ridges. The latter structures are, of course, a relic of Cidarid characters. This shows that the change from an interradial to a radial position for the perignathic prominences was a gradual one. The view that the increasing complexity of ambulacral structure is connected with the growth of the perignathic processes, which hinder the passage of the ambulacra on to the peristomial membrane, is supported by Bather (*t. c.*) on this evidence.

There are, then, two orders of Echinoidea from which, on stratigraphical evidence alone, the Holoctypoida may have been evolved. Of these orders, the Cidaroida were well established, with their special structures stereotyped, before there is any evidence of the existence of Irregular Echinoids. This fact alone would seem to render unlikely any hypothesis which regarded the early Cidaridæ as directly ancestral to the Holoctypoida.

When consideration is taken of the essential features of a *Pygaster*, a notable correspondence between them and the structures of the early Diademoida becomes apparent. The ambulacra are chiefly composed of primaries (with a triple arrangement of tubercles), and towards the peristome a partial compression of the plates into triads is seen. Triad formation, in the same part of the ambulacra, is characteristic of all the early Diademoids, and is one of the diagnostic features of the whole order. The perignathic girdle of *Pygaster* shows well-developed processes, but hardly appreciable ridges. This character, the absolute antithesis to that of the Cidaridæ, is known to have been gradually attained by the Diademoids through their Triassic and Liassic representatives. Again, the apical system of *Hemipedina* often shows a prolongation backwards into the posterior interambulacrum.

Most significant of all is the indication of affinity between the two orders by the slight ontogenetic evidence already available. In discussing the affinities of *Hemipedina bonei*, Wright (20) admitted that he was uncertain as to the true generic relations of the species. He was at one time inclined to class it with *Pygaster*. Bather (59) has referred to this species, and is of the opinion that *H. bonei*, if it is not a *Hemipedina*, should be associated with *Pygaster*. The species is a small one, and the shape

of the scar left by the apical system indicates a considerable backward prolongation of that structure. I have before me a series of ten specimens from the Pea Grit of Crickley Hill (near Cheltenham), which are presumably the young of *Pygaster semisulcatus*; but I am unable to find any satisfactory distinctions between them and the type of *H. bonei*. If there is any appreciable difference, it consists in the fact that the periproct does not project so far into the posterior interambulacrum in the *Pygasters* as does the "scar of the apical disc" in the *Hemipedinæ*. It seems hardly possible that, so early in the history of both orders, heterogenetic homöomorphy could have reached such a degree of perfection, and I am therefore strongly of the opinion that "*Hemipedinæ*" *bonei* is a *Pygaster*, and almost certainly a young form of *P. semisulcatus*.

It thus seems established that *Pygaster* is intimately related to some primitive, probably Liassic, Diademoid. It is impracticable, in the present state of our knowledge, to search for the actual generic ancestor; but if the choice were to lie between *Diademopsis* and *Hemipedinæ*, the former would seem to possess the stronger claim to recognition. As defined by Lambert (52), *Diademopsis* is distinguished from *Hemipedinæ* by the presence of pronounced secondary tubercles in the interambulacra. Bather (59) has shown that the distinction is not so absolute as Lambert's diagnosis would suggest, but the fact remains that, among the earlier species of the genera, there is a more strongly developed tendency to a multituberculate character in *Diademopsis*. As *Pygaster* is also a multituberculate form, the alliance with *Diademopsis* would seem natural, but I do not feel justified in expressing a positive opinion on the matter, beyond the statement that the immediate ancestor of the Holoctypoida must surely have been a Diademoid.

3. The *Pygasteridæ* and *Conulidæ*.

The three subgenera of *Pygaster* sens. lat. mark three stages in the evolution of that genus. *Pygaster* sens. str. is undoubtedly the most primitive type. *Megapygus* shows an advance in two directions. The periproct is undergoing a change of shape preliminary to its actual separation from the apical system, and the tuberculation is assuming slight irregularity of arrangement. Both these features point towards "Irregularity." *Macropygus*, which appeared at about the same horizon as *Megapygus*, shows a similar character in its periproct, but the tuberculation, instead of becoming superficial and irregular, shows a deepening of the scrobicules, and a corresponding reduction of the miliary surface. The distinction from the *Megapygus umbrella* group is not very great in appearance, but seems important in its results. I regard the two subgenera as parallel lines springing from the common ancestor *Pygaster* sens. str.

Pileus is undoubtedly a short-lived offshoot from the *Pygaster*-

stock, for the anomalous biserial ambulacra are unlike any other genera of the order. The periproct position shows an advance on the *Megapygus*-condition, and, owing to certain irregularities of the tuberculation, I am inclined to regard *Pileus* as a side-branch of that line. *Anorthopygus*, which in the classification I have associated with *Pileus*, seems to show a course of evolution parallel with, although in many ways differing from, that of the aberrant genus. The oblique position of the periproct does not appear to be an important character, although peculiar. The tuberculation is definitely like that of *Macropygus* in structure, though not in arrangement, and therefore I have regarded it as an offshoot from that subgenus in Lower Cretaceous times, which corresponded with the similar offshoot from the *Megapygus*-line in the Upper Jurassic.

At about the same horizon in which *Anorthopygus* occurs, *Conulus* appears. The earlier species seem very difficult to distinguish from those of *Pyrina* with which they may be stratigraphically associated. In the matter of the tuberculation the adoral surface of *Conulus* shows much the same characters as the whole test of *Anorthopygus*. Moreover, the arrangement of the tubercles is similar in both genera. The periproct has passed to the posterior edge of the test, although in many young specimens of *C. subrotundus* (some of which are almost globular), the aperture is on the adoral surface quite near to the apex. The feature which marks off *Conulus* so sharply from the Pygasteridæ is the accelerated condition of the ambulacral plate-crushing. There is no appreciable tendency to increase the number of demi-plates in the Pygasteridæ, from the few adorally situated ones, which were probably directly inherited from the Diademoid ancestor. However, in many other features *Conulus* shows almost equal acceleration. When the Upper Chalk is reached, the genus disappears suddenly after a short existence, during which few important specific modifications were evolved. Its relations to the Pygasteridæ are not very easy to decide, but, on the character of the tuberculation, I have connected it with the *Anorthopygus*-line. An additional link between the genera is afforded by the structure of the apical system, the fifth genital plate being permanently absent from both.

4. The Discoidiidae.

Holactypus sens. str. appears in the Inferior Oolite in association with *Pygaster* sens. str. It is only in the position of the periproct that considerable acceleration is shown, but the differentiation of the characters of the tubercles on the upper and lower surfaces of the test is also a feature of advance. The Holactypinæ are a perfectly homogeneous group, and must be regarded as an unbroken series. *Coptodiscus* is apparently a peculiarly specialized offshoot from *Cænholactypus*, and the suturing of the adapical surface may perhaps be ascribed to

gerontic degeneration of armour (see Oswald, 61). *Lanieria* is also allied to *Cænholectypus*, but, unlike most of the *Holectypinae*, is almost globular in shape. The position of *Discholectypus* is more difficult to determine. In every obvious feature it is a true *Holectypine*, but it shows an ambulacral structure closely resembling that of *Conulus*. The absolute contrasts of tuberculation, periproct-position, apical structure, and general form which appear when *Discholectypus* and *Conulus* are compared, preclude any possibility of a genetic connection between the genera. *Discholectypus* would seem, therefore, to be a branch of the *Holectypus*-line, which developed complex ambulacral plating by a process of acceleration. This parallelism of development (heterogenetic homœomorphy) of a feature in two distinct genera is rendered particularly interesting by the correspondence in time at which the specialization took place.

There can be no doubt as to the close relationship which exists between *Discoidea* and *Holectypus*. On stratigraphical evidence, and also because of the variable nature of the apical system (in the matter of the perforation of the posterior genital plate), I have considered the *Discoidiinae* as descendants of *Holectypus* sens. str., whose appearance coincided in time with the modification of the parent stock into *Cænholectypus*.

5. Summary of Internal Evolution.

The *Holectypoida* originated from a *Diademoid* ancestor in the Triassic or early Liassic periods, and subsequently developed along two definite lines. In one line (*Pygasteridae* and *Conulidae*) the apical system never fully regained, and finally lost, the posterior genital plate, while the whole system tended to become elongated; the tuberculation gradually became uniformly distributed over the interambulacra, and irregular in its arrangement; the shape of the test showed various departures from radial symmetry; and the jaw-structures dwindled and ultimately almost disappeared in adults. In the other line (the *Discoidiidae*), the fifth genital plate was early redeveloped, and later regained its function, while the system as a whole became circular in shape: the tuberculation retained its regularity of arrangement, but became insignificant adapically and coarse adorally; the shape of the test eventually regained a radial symmetry; and the jaws, though modified, showed little or no decrease in power.

VI. THE EXTERNAL AFFINITIES OF THE ORDER.

The primitive character of the early *Holectypoida* (in an Irregular sense) is so pronounced that it would naturally be expected that the group existed for some time before any of the more elaborate forms were evolved, and that these appeared at subsequent intervals as offshoots from the *Holectypoid* stock. Such, however, was not quite the case. The *Holectypoids* are

merely a retarded series of Irregular Echinoids, and some of the orders of that subclass early became differentiated from the Pygasteridæ by a relatively accelerated evolution. It is becoming increasingly manifest that large groups of organisms, such as the Irregular Echinoids, are not often homogenetic in the strict sense of the word. When a series of forms that have been regarded as belonging to an individual genus can be shown (as Beecher and others have proved for some Brachiopoda) to pass through widely divergent lines of ontogenetic (and therefore phylogenetic) development, the problem of the evolution of a class or subclass must be considered more complex still. Indeed, at first sight, it would seem that, without the evidence of Ontogeny, no reliable clue to genetic relationship can be deduced from even the most accurate correspondence of adult characters.

Stratigraphical palæontology, however, shows a kind of extended ontogeny which, although fragmentary, is infallible so far as it can be understood. The same phenomena which complicate the study of recapitulation in recent species are as widely developed among the families and orders of past periods. Acceleration and retardation, adaptation and degeneration, tend to obscure the true sequence of genetic affinity to such a degree that, in the present state of knowledge, only the bare outlines of the evolution of the larger groups can be indicated.

In this section of the paper, an attempt is made to show the affinities (with persistent regard to stratigraphical relations) which appear to link certain genera of the Holoctypoida with those of other orders. Little account is taken of the subsequent changes which may have been developed in these other groups, and no opinion is expressed as to their absolutely homogenetic characters. The name of a fairly primitive member of each main group is inserted in the diagram (text-fig. 60, p. 493) in its true stratigraphical position, and by a thin vertical line each of these names is connected with that of a characteristic genus now living, which is usually regarded as belonging to the same group.

1. *Pygaster* and *Galeropygus*.

Galeropygus appears in the Upper Lias with at least two species, one of which (*G. dumortieri* Paris) is British. The genus is thus contemporaneous with *Pygaster* sens. str. Gregory (50), probably on account of its obviously primitive characters, included it among his Pygasteridæ, although in almost every feature it offers a violent contrast to the diagnosis of that family. Practically the only diagnostic character in which it resembles an Holoctypoid is the apetaloid nature of its ambulacra. A feature which would tend to connect it with some of the later *Pygasters* (e. g., *Macropygus truncatus*) is the shape of the test, which is commonly rather broader than long. The deep anal sulcus finds a shallow counterpart in the posterior interradius of *Pygaster semisulcatus*, but I have indicated above (p. 465) that this sulcus

is probably due to the presence of the periproct near the apex, and has, in consequence, little direct phylogenetic meaning.

Galeropygus may be regarded as differing from *Pygaster* sens. str. by a marked acceleration in the characters of its tuberculation and peristome. The former feature is already in the uniform condition, no definite order of appearance being traceable for individual tubercle series. The peristome is quite small, and slightly excentric anteriorly, with no visible adaptation for jaws. I regard the genus as a primitive member of the *Nucleolites*-group, with all the characters of that group except the subpetaloid ambulacra. As there is a marked tendency to develop this feature even among the Holoctypoida, it seems that its production in the descendants of *Galeropygus* could be naturally postulated. Owing to the stratigraphical appearance of *Galeropygus*, I should consider it an offshoot from the Diademoida that hardly, if at all, progressed along the Holoctypoid line of descent before developing striking acceleration in all its characters except the periproct and the ambulacra. It is interesting to find that the position of the periproct remained more or less constantly primitive in the majority of the Jurassic descendants of *Galeropygus* (e. g., *Echino-brissus* and *Clypeus*), although the ambulacra early began to show elaboration. In the periproct feature, indeed, the Pygasteridæ show a greater acceleration than the Nucleolitidæ, although the Holoctypoida are, in most characters, a retarded group.

Even if the affinity between *Galeropygus* and *Pygaster* were to be proved to be less close than I have indicated in the diagram, the characters of the ambulacral plating would show that it was derived, directly or indirectly, from a Diademoid ancestor. As I interpret the relations of the genera at present, *Galeropygus* and *Pygaster* stand together at the root of all the Irregular Echinoids, in structure as well as in stratigraphical position. The subsequent modifications of the *Galeropygus* stock I have briefly outlined in a recent paper (Hawkins, 66), and I hope to amplify that readjustment of the classification of the "Cassidulidæ" at some future time.

2. *Pygaster*, *Conulus*, and the Echinoneidæ.

Since its first recognition by Desmoulins (4), the genus *Pyrina* has been the occasion of great confusion. The extraordinary similarities that appear when it is compared with *Conulus* make the generic position of species ascribed to them more difficult to determine than their specific distinctions. Such a form as *P. desmoulinsi*, with its elongated ovoid ambitus, is easily distinguishable from a *Conulus*, the species of which are almost, though rarely quite, circular in outline. To restrict the genus *Pyrina* to such elongated forms would, however, result in a very unnatural grouping of the species, and, unless details of the anatomy can be traced, the distinction of a roughly circular *Pyrina* from a *Conulus* becomes almost impossible. Theoretically

a *Conulus* should possess vestiges of jaws, and a peculiar type of perignathic girdle; but jaws are very rarely preserved in fossil Echinoids, and *Pyrina* has a somewhat similar series of structures around the peristome. The similarities between the two genera include the shape (generally), the oblique peristome, the position and shape of the periproct, the structure and arrangement of the tubercles, the ambulacral plating, and the composition of the apical system. Added to these there would probably be the presence of vestigial jaws in young individuals of *Pyrina*, since these structures have been found in a small specimen of the more highly specialized *Echinoneus*. An additional difficulty in the separation of species belonging to the two genera results from the fact that both were evolved at about the same time, and flourished side by side during the Cretaceous period.

So many correspondences in important structures cannot point otherwise than to a close genetic affinity between *Pyrina* and *Conulus*, and the only feature that can be considered to exclude the former genus from the Holoctypoida is the absence of jaws in the adult state. The presence of these organs in young specimens cannot be considered sufficient evidence for the inclusion of *Pyrina* in the order; for, if vestigial characters are taken into account in classification, by analogy the Mammalia, by reason of their embryonic gills, would have to be classed with the Pisces.

The earliest members of the Echinoneidæ, such as *Nucleopygus*, have the periproct in a supra-marginal position similar to that of *Anorthopygus*. As Lovén (36) has shown, a gradual migration of the periproct takes place in this family along an exactly parallel line to that passed through in the Holoctypoida, until in *Echinoneus* the anus is in a position similar to that of *Discoidea*. The features of *Desorella* are so little known that it is unsafe to ascribe a definite systematic position to it, and it has been ignored for the purposes of the present work. I have regarded the Echinoneidæ as offshoots from *Pygaster* (*Macropygus*) in Upper Jurassic times, which for some distance followed the *Anorthopygus* branch, and left it simultaneously with the Conulidæ. They were at first distinguished from that family by the accelerated degeneration of their jaw-structures.

3. *Anorthopygus* and the Spatangidæ.

The earliest members of the Spatangidæ proper appear in the Lower Cretaceous. They are not very clearly distinguishable from some other groups, especially from the Echinocorythidæ. The structure of the apical system is, however, different in these two families. The system of the Echinocorythidæ is elongate, and has been compared with that of the Collyritidæ. (I have recently shown (Hawkins, 70) that this structure could easily be evolved from the Conulid type by acceleration.) The Spatangidæ have a compact apical system, which often nearly resembles that of the Conulidæ, but is sometimes ethmolysian—that is, with the

madreporic genital extending right through the system to occupy some part of the posterior border.' In every case the fifth genital is absent, and this feature alone serves to distinguish a Spatangid from the great majority of the "Cassidulidæ." At first sight there do not seem to be many points of resemblance between *Anorthopygus* and the Spatangidæ. However, the stratigraphical appearance of the two types is the same, and, in the structure of the apical system, *Anorthopygus* shows an ethmolysian character in both the known species. No types of Echinoids other than *Anorthopygus* and some Spatangids have this feature. The position of the periproct in the Holecypoid genus is about midway between the apex and the ambitus, and the same character holds in almost all the Spatangidæ. In several small specimens of *A. orbicularis* that I have seen there is an appreciable increase in the declivity of the test behind the periproct, and I regard this as a rudimentary posterior surface. The plating of the periproct-membrane also shows some similarity in the two groups.

The evidence for their genetic affinity is very slight, but I have ventured to connect the Spatangidæ with the *Anorthopygus* line of descent on account of the apical structure and stratigraphical correspondence.

4. *Conulus* and *Amblypygus*.

Amblypygus is a Tertiary Echinolampid (Duncan (44) classed it as an Echinoneid) whose characters are best known from the descriptions of Indian species given by Duncan and Sladen (39). The shape of the test, the obliquity of the peristome, and more especially the structure of the ambulacra, all show features of similarity with those of the Conulidæ. The ambulacra are sub-petaloid adapically in *Amblypygus* (a marked contrast to all the Echinoneidæ), but in that region, as much as on the adoral surface, the inclusion of one demiplate between two primaries is regularly shown. It is difficult to imagine that this peculiar structure could be evolved independently in heterogenetic genera. The only other form with which *Amblypygus* could be associated by reason of this structure is *Discholectypus*, but, apart from the contrasts which the two genera show in other respects, the stratigraphical sequence is not favourable. As *Amblypygus* is a very primitive type, and one of the oldest known genera, of the Echinolampidæ, I have separated that family from the other "Cassidulidæ," and derived it from the Conulid stock. The later members of the family seem to have reduced their ambulacral structure to a condition of simple primaries; a process that, outside the order of the Holecypoida, seems to have been the usual one adopted.

5. *Conulus* and *Conulopsis*.

A group of Upper Cretaceous Echinoids, which was formerly classed with "*Galerites*," was separated from that genus by

Desor (21) under the name of "*Echinoconus*." "*Galerites roemeri* d'Orb., on which the genus was founded, seems to be congeneric with the "*Echinoconus abbreviatus*" and "*orbignyanus*" of the Upper Chalk of Norfolk. The differences between these species and a typical *Conulus* are manifold, and, as the name *Echinoconus* cannot be retained for them, I have distinguished them as *Conulopsis*. The tuberculation of *Conulopsis* is irregular, and the tubercles of the adapical surface have deeply sunken scrobicules. The ambulacra are composed of primaries throughout, the adapical pore-pairs being almost subpetaloid; while round the peristome the interambulacra are raised into definite "bourrelets." The general facies of *Conulopsis* is similar to that of *Caratomus* (the latest discussion of this genus being by Schlüter, 54). It is possible, however, that some real genetic relation may exist between the later *Conuli* and *Conulopsis*, and that the resemblance of the latter genus to *Caratomus* may be deceptive. Even if *Conulopsis* is a descendant of *Conulus*, it is certainly not an Holoctypoid. It would show a development which would have a peculiar interest when compared with the development of *Conoclypeus* from *Discoidea*. The same loss of regularity in the tuberculation is seen, and the ambulacral plates have become restored to their primary state. (The large polygonal ambulacrals of the adoral surface of *Conulopsis* are strikingly similar to those of a *Clypeaster* or of a Spatangid.) The development of a subpetaloid character in the adapical parts of the ambulacra would be comparable in the two genera, while a similar correspondence is shown in the peristomial "bourrelets." Only the position of the periproct (almost marginal in *Conulopsis*), and the presence of strong jaws in *Conoclypeus*, would tend to separate the two genera. These last features would be definitely due to the characters of the ancestor, *Conulopsis* agreeing in them with *Conulus*, and *Conoclypeus* with *Discoidea*.

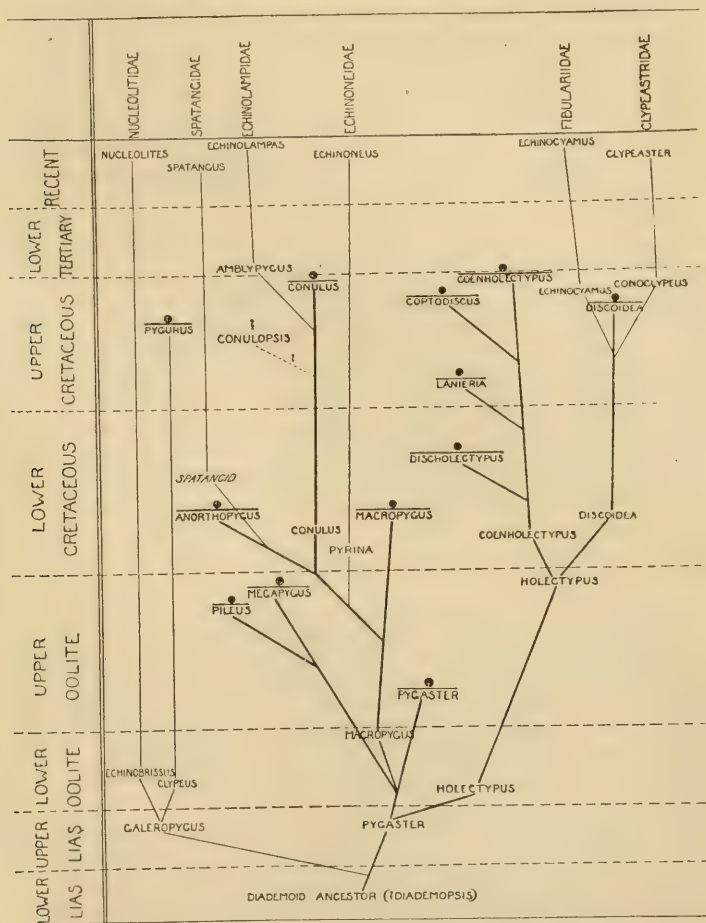
Conulopsis and *Conoclypeus* would then mark parallel accelerations from different branches of the Holoctypoid stock. At present, however, I do not feel satisfied that the genetic connection between *Conulus* and *Conulopsis* exists, but I have connected the two by a broken line in the table.

6. *Discoidea* and the Clypeastroida.

The similarities of structure that link the Discoidiinae with the Clypeastroida are many and of fundamental importance. A circular outline; an invaginated peristome; an infra-marginal periproct; a madreporite scattered over five genitals, all of which may be perforated by a genital pore; and internal buttresses to the test: are common to most genera of the Clypeastroids, and are diagnostic features in *Discoidea*. The jaws in this genus are strong, in view of its late appearance among the Holoctypoida, and, although conforming more to the "Regular" than to the Clypeastroid type, may well have assumed a more expanded

shape when the height of the test diminished. The ambulacra in all Clypeastroids are either petaloid or subpetaloid, but *Conoclypeus*, from the Upper Cretaceous, serves to link the simple

Text-fig. 60.



Phylogenetic table of the Holcetoypoida and their allies. Names of Holcetoypoid genera are connected by thick lines, those of other orders by thin lines. No details are inserted in groups other than the Holcetoypoida, the names in the external groups being those of the earliest-known genus that has been satisfactorily described. Short, thick, horizontal lines above names indicate that the genera became extinct at that horizon, and left no direct descendants.

ambulacral pores of *Discoidea* with the more elaborate structures of the later genera. Perhaps, if the jaw-structures of *Conoclypeus* were to be discovered in a more perfect condition than

those described by de Loriol (35), they also would show an intermediate character. The presence of "bourrelets" round the peristome in this genus are the only features that seem antagonistic to its being regarded as ancestral to the *Clypeaster*-series.

The similarity between the small species of *Discoidea* and *Echinocyamus* caused Gregory (50), when revising the unnecessary generic division of "*Echinites*" made by Duncan (44), to propose the name *Protocyamus*. The name is inadmissible on systematic grounds, but would be morphologically appropriate. *Echinocyamus* occurs first in the Upper Cretaceous, and has developed but few changes in structure from that time to the present day. H. L. Clark (64) has recently suggested that the characters of *Echinocyamus* are not primitive, but rather degenerate. On the stratigraphical evidence I incline to regard them as truly primitive, and to have retained ancestral traits by the retardation of development consequent on their small size.

Echinocyamus (of the Fibulariidae) was then directly evolved from the smaller (typical) *Discoidea*, while *Conoclypeus* (of the Clypeastridae) appeared at the same period as a descendant of (probably) the larger species of *Discoidea* (the "*Pithodia*" of Pomel, 37). The former group underwent little change in subsequent periods, but the latter became rapidly differentiated into the numerous and complex types that characterize the other families of the Clypeastroida.

VII. SUMMARY.

The Holactypoida are restored to the rank of an order of the Echinoidea Irregularia. A classification, somewhat modified from that proposed by Gregory (50), is given, and revised diagnoses of the families, subfamilies, and genera are drawn up. A comparative study of the morphology of the skeletal structures of typical genera of the group is given; and, in the light of the results of this study, the course of evolution both within and beyond the limits of the order is indicated.

The Holactypoida are regarded as an annectant group of the Irregular Echinoids, whose characters retain a considerable uniformity owing to a persistent retardation of evolution. At various periods offshoots from the Holactypoid stock appeared, which, usually with a relatively accelerated differentiation, developed into the various orders and families of the Irregularia. The order commenced in the Liassic period, and became extinct at the end of the Cretaceous. Two of the groups of Echinoids now living retain many features that were characteristic of the Holactypoida (the Echinoneidae and the Fibulariidae). The other groups of Irregular Echinoids show a much greater departure from the primitive character, but they all possess some features which indicate their Holactypoid ancestry.

Two new names are introduced in the Systematic Part:—*Megapygus* as a subgenus of *Pygaster*, corresponding with the *Pygaster* (sens. str.) of Pomel (37), with type *M. umbrellæ*; and *Conulopsis*, a genus including the "*Echinoconus*" of Desor (21), with type *C. roemeri* d'Orbigny. The latter group will be studied in greater detail in a forthcoming paper.

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EXHIBITIONS AND NOTICES.

March 19, 1912.

S. F. HARMER, Esq., M.A., Sc.D., F.R.S.,
Vice-President, in the Chair.

Mr. A. RADCLYFFE DUGMORE, F.R.G.S., gave a lantern exhibition of a large number of photographic studies of wild animals in British East Africa and Newfoundland. This very beautiful series of pictures was briefly described by Mr. Dugmore, who dwelt particularly on the advantage to be gained by hunting with the camera, and showed that it was a sport as well as a means of securing interesting and valuable material.

Messrs. E. GERRARD & SONS sent for exhibition:—

(a) A very fine head of a cow Sable Antelope (*Hippotragus niger*), shot by Major E. C. F. Garraway, C.M.G., which was of interest in that the mane was white instead of the normal dark brown, and in the horns also being near the record for length.

(b) The skull of an Isabelline Bear (*Ursus isabellinus*) with eight well-marked incisors in the lower mandible instead of the normal six.

(c) The skull of a Leopard (*Felis pardus*) with an injury to the nasals and premaxillary bones which had arrested the shedding of the milk-canines and the growth of the permanent canines. The skull was quite adult and the remaining teeth were fully developed and normal.

(d) The skull of a Lion (*Felis leo*) showing a severe injury or disease of the left side of the palate and the upper mandible, which had not affected the growth of the teeth.

Two new Genera and a new Species of Viverrine Carnivora *.

MR. OLDFIELD THOMAS, F.R.S., F.Z.S., exhibited an example of a Viverrine Carnivore from Tonkin which had a striking external resemblance to the common *Hemigalus* † *hardwickei*, but which differed so much in the skull and dentition as to necessitate its being considered a distinct genus. Reason was also given for regarding the Bornean "*Hemigale*" *hosei* as representing a third genus of the group.

The following was Mr. Thomas's account of the animals referred to:—

"Commencing with the known species, from Borneo, I propose

* [The complete account of these new genera and the species is given here, but since the names and preliminary diagnoses were given in the 'Abstract,' they are distinguished by being underlined.—EDITOR.]

† Better, but erroneously, known as *Hemigale*.

to found the following genus for '*Hemigale*' *hosei*, which I have long realized should be separated from the banded animals forming the true genus *Hemigalus*.

"DIPLOGALE.

"Thomas, Abstract P. Z. S. 1912, p. 18 (March 26).

"Pattern of coloration normal, not banded.

"Skull with parallel-sided, square-fronted muzzle, the tooth-rows nearly parallel. Septum between anterior palatine foramina without mesial foramen. Meatus and bulla about as in *Hemigalus*.

"Teeth:—Upper incisors forming a straight transverse line, the outer pair scarcely set back behind the level of the others. Middle teeth (p^1 , m^1) of the cheek-tooth series proportionally small, terminal ones (p^1 , m^2) comparatively large. P^1 as long antero-posteriorly as p^2 , with two roots and both anterior and posterior supplementary cusps. P^2 also with marked supplementary cusps, and a postero-internal basal cusp, this being quite absent in *Hemigalus*.

"Type, *Diplogale hosei* (*Hemigale hosei* Thos.). Animal and skull described and figured P. Z. S. 1892, p. 222, pls. xviii. & xix.

"The different shape of the muzzle and palate, the double-rooted p^1 and other differences in the teeth, and the essential difference in the pattern of coloration are the chief reasons for distinguishing this genus from *Hemigalus*.

"CHIROTOGALE.

"Thomas, Abstract P. Z. S. 1912, p. 17 (March 26).

"Pattern of coloration as in *Hemigalus*, not as in *Diplogale*.

"Skull—at least in the young—shaped more or less as in *Eupleres*, the muzzle long and slender and the premaxillæ drawn out forwards, with an abnormally long gap between the last incisor and the canine. Median septal foramen between anterior palatine foramina excessively long, as broad as either of the lateral foramina, and nearly twice their length. Auditory region with the bullæ small and narrow, and the meatus very large and open, its diameter approximately equal to that of a cross-section of the bulla itself.

"Teeth (of a young specimen with the milk-teeth still in place).—Upper incisors quite unique in shape among Carnivora, broad, flattened, spatulate, with a straight cutting-edge, the edges of the six combined forming nearly a half-circle, owing to the position of i^2 partly behind the level of i^1 , and of i^3 again quite behind it—the general outline of the incisive dentition recalling more that of some of the smaller Kangaroos than that of a Carnivore. P^1 small, single-rooted. Milk-premolars 2, 3, and 4 small and delicate, much smaller than the corresponding teeth of *Hemigalus* and *Diplogale*, the proportions more as in *Eupleres*. Lower incisors again broadened terminally, spatulate, the third with a broader blade than the other two.

"Type:—

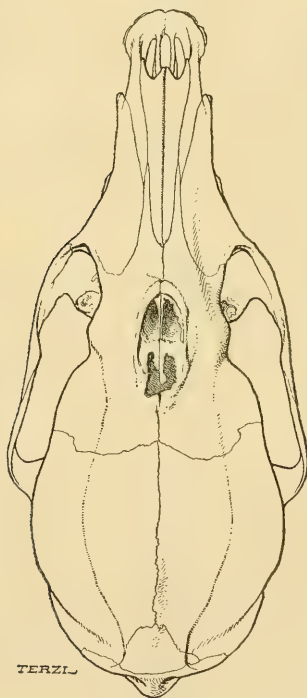
"*CHROTOGALE OWSTONI*. (Text-figs. 61–63.)

"Thomas, Abstract P. Z. S. 1912, p. 17 (March 26).

"Colour and other external characters as in *Hemigalus hardwickei*, except for the differences indicated in the following description:—

"Size apparently about as in *H. hardwickei*, but the only specimen immature. Fur longer and less sleek than in that animal, the longer hairs of the back, in a half-grown specimen, about 19 mm. in length. Fur of upper side of neck all smoothly directed backwards, like that of the back, instead of being sloped forwards from a whorl on the withers.

Text-fig. 61.



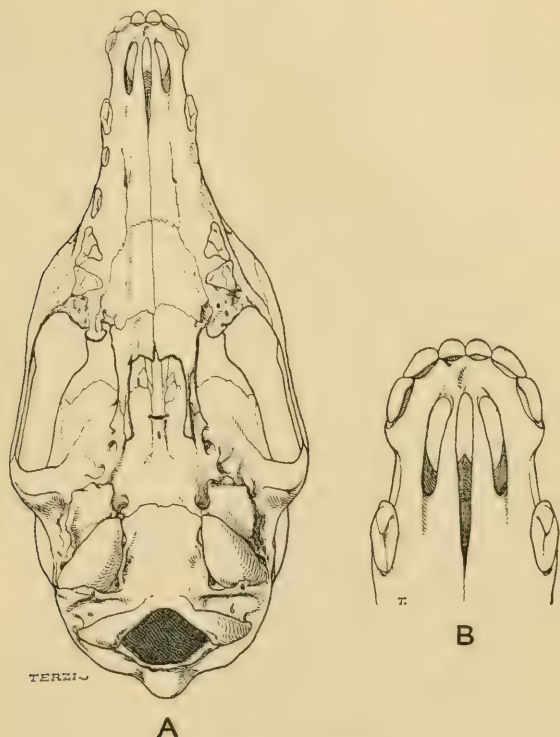
Chrotogale owstoni.

Upper view of skull. The opening in the frontal region is probably of parasitic origin.

"General colour-pattern in most respects as in *H. hardwickei*, but the dark dorsal bands are continued rather lower down on the sides of the belly, where also there are a certain number of

small irregular dark spots; on the neck the two dark bands are broad and sharply defined, and outside them, on the sides and under surface of the neck, there are similarly a number of blackish spots, such dark markings in this region being quite absent in *H. hardwickei*. Light ground-colour of upper part lighter than in *H. hardwickei*, whitish instead of buffy. Under surface pale buffy. Limbs greyish white, the digits scarcely darker. Tail as in *H. hardwickei*, except that the terminal dark-coloured half is more bushy, the hairs attaining a length of over 30 mm.

Text-fig. 62.

*Chrotogale owstoni*.

A. Palatal aspect of skull. | B. Anterior part of muzzle, enlarged.

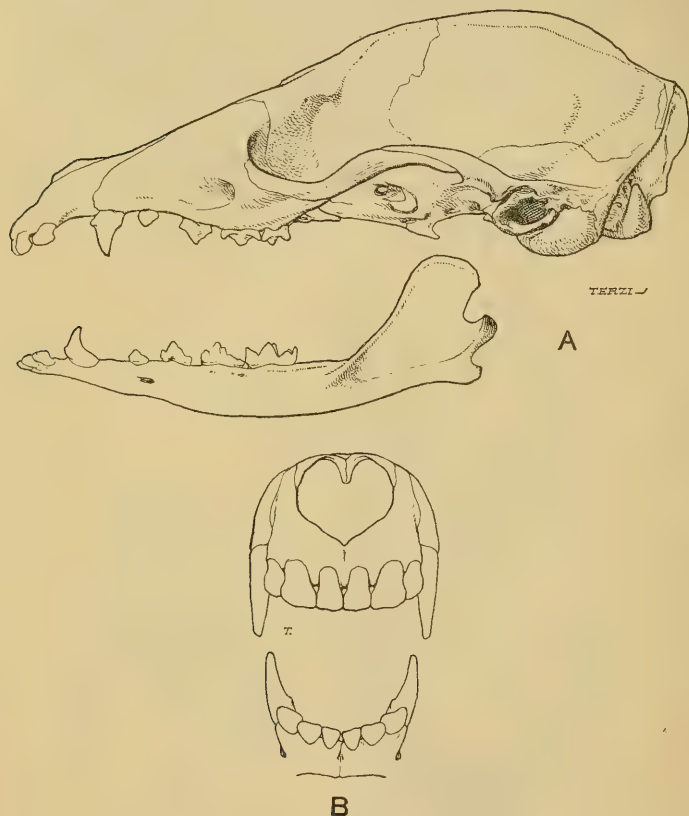
"Skull and teeth as described above, the description being based on a specimen with milk-dentition. Adult dentition unknown.

"Dimensions of the type, measured on the skin:—Head and body (c.) 400 mm.; tail 260; hind foot 70.

"Skull: greatest length 91 mm.; condylo-basal length 85; zygomatic breadth 39.5; nasals 22; interorbital breadth 15; breadth

of brain-case 33·7; palatal length 46·5; breadth between outer corners of mp^1 21·7; palatal foramina 7·2; median septal foramen 11·6; horizontal length of mi^1 2, mi^2 3, mi^3 3·3, mp^2 4·6, mp^3 5·4, mp^4 3·9.

Text-fig. 63.



Chrotogale owstoni.

A. Side view of skull. | B. Front view of muzzle.

“*Hab.* Yen-bay, on the Song-koi River, Tonkin.

“*Type.* Young male. B.M. No. 12.4.21.3. Original number 11. Collected 16 September, 1911, by Mr. Alan Owston's collector Orii.

“This remarkable animal would at first sight be regarded as merely a local representative of the well-known Banded Civet (*Hemigalus hardwickei*), but a study of its skull and dentition, although only at present represented by a young specimen, shows that it is a most peculiar form, parallel in some respects with the anomalous genus *Eupleres*, while in others—notably in its almost

kangaroo-like incisors—it is quite unique among Carnivora. And, again, granting its essential distinctness from *Hemigalus*, its really striking external resemblance to that animal is not the least of its many peculiarities.

“It is to be hoped that adult specimens may soon be obtained, so that we may learn the characters of the permanent dentition. Observations on its habits and food will also be of the greatest interest.

“I have named the species in honour of Mr. Alan Owston, of Yokohama, to whose enterprise in sending an expedition to Yunnan its discovery is due.”

A new Snub-nosed Monkey.*

MR. GUY DOLLMAN exhibited a new species of Snub-nosed Monkey, allied to *Rhinopithecus bieti* M.-Edw., collected at Yen-bay on the Song-koi River, Tonkin. He proposed to call this new form *Rhinopithecus avunculus*, and described it as follows:—

RHINOPITHECUS AVUNCULUS.

Dollman, Abstract P. Z. S. 1912, p. 18 (March 26).

Size smaller than in *Rhinopithecus bieti* M.-Edw., with dorsal surface of body black and under parts yellowish buff.

Size and general proportions of body much less than in *bieti*; tail considerably longer. Hair shorter than in any of the other forms, the general appearance more that of a true *Presbytis* than a *Rhinopithecus*. No well-marked crest on crown of head, the hairs in this region only slightly longer than on the neck; in *bieti* a conspicuous crest is present in both sexes. Ears not concealed by dense tufts of hair, rather more marked than in the Mekong species. General colour of dorsal surface deep black, tinged with brownish on the crown and nape; the black coloration extends all over the dorsal surface, both of body and limbs. Sides of face and forehead creamy-white tinted with buff, the colour gradually darkening on the back of the forehead and merging into the dark blackish brown of the crown. Supra-orbital line of stiff black hairs well developed. Face around eyes naked and apparently flesh-coloured; a crescent-shaped row of creamy-white hairs extending from the temporal region on to and across the cheek. Sides of neck orange-buff, the bright buff-coloured hairs forming a most conspicuous border to the dark-coloured nape. Ears with creamy-white tufts arising from their inner sides. Rump with two prominent buffy-white patches on either side of the tail, connecting with the light-coloured markings on the backs of the thighs, but not forming the large conspicuous light-coloured areas such as occur in *bieti*. Backs of hands and feet covered with rather short black hairs, the hair not sufficiently

* [The complete account of this new species appears here, but since the name and a preliminary diagnosis were published in the 'Abstract' it is distinguished by being underlined.—EDITOR.]

long to conceal the digits nor extending over the nails. Entire ventral surface of body yellowish buff, the buff tint most dominant on the throat and anterior portion of the belly; no trace of any grey or dark-coloured hairs on the chest and neck. Inner sides of arms yellowish white, the colour almost white at the elbow and visible from above as a light cream-coloured border, the contrast between the black hairs on the outer side and the bright yellowish white of the inner side of the arm being most marked. The light yellowish colour extends right down the inner sides of the limbs as far as the hands and feet, where it is somewhat duller and dirtier. Tail long, measuring 100 mm. longer than that of *bieti*; clothed with comparatively short hairs, except at the tip, where the hairs are rather longer and form a distinct tuft. Colour, above dark black mixed with creamy-white down the mid-line with a creamy-buff border; terminal tuft almost pure white, faintly washed with pale buff; ventral surface considerably lighter.

Skull like that of *bieti* as regards the general shape, but smaller and with smaller cheek-teeth. Supraorbital region rather more like that of *roxellance* than of *bieti*; muzzle formed as in the latter species, without any well-marked concave depression of the premaxillary region. Interorbital breadth less than in *roxellance*. Zygomatic arches almost parallel, not expanded laterally.

Dimensions of the type (measured in the flesh):—

Head and body 520 mm.; tail 660; hind foot 165; ear 40.

Skull: greatest length 109 mm.; basilar length 68; zygomatic breadth 77; greatest breadth across orbital region 72·5; greatest diameter of orbit 28; interorbital constriction 11; greatest width of cranium 68·3; palatilar length 32·9; width of palate (inside m^1) 20·5; length of upper tooth-row, from front of first premolar to back of last molar, 30.

Hab. Yen-bay, Song-koi River, Tonkin.

Type. Adult female. Original number 8. Collected by Mr. Alan Owston's collector, Oriei, on September 14, 1911.

This interesting Monkey was readily distinguished from its nearest ally, *Rhinopithecus bieti*, by its dark black back, yellowish-buff underparts, and light-coloured tail.

A young specimen, sent with the type, was coloured in much the same manner as the adult, only very much paler, the crown of the head and hind limbs being yellowish tinged with grey, whilst the back was just commencing to become dark. The entire underparts were, as in the adult, a rich yellowish-buff colour.

In the course of describing this new Snub-nosed Monkey, Mr. Dollman had been in correspondence with Prof. E. L. Trouessart, of the Paris Museum, concerning the specimens of *Rhinopithecus bieti* under his charge, and was indebted to Prof. Trouessart for much valuable assistance, most liberally given. Without this assistance the description of this new *Rhinopithecus* would have been a far more difficult matter.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

March 19th, 1912.

S. F. HARMER, Esq., M.A., Sc.D., F.R.S.,
Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

MESSRS. E. GERRARD & SONS sent for exhibition :—

(a) A very fine head of a cow Sable Antelope, shot by Major E. C. F. Garraway, C.M.G., which was of interest in that the mane was white instead of the normal dark brown, and in the horns also being near the record for length.

(b) The skull of an Isabelline Bear with eight well-marked incisors in the lower mandible instead of the normal six.

(c) The skull of a Leopard with an injury to the nasals and premaxillary bones which had arrested the shedding of the milk-canines and the growth of the permanent canines. The skull was quite adult and the remaining teeth were fully developed and normal.

(d) The skull of a Lion showing a severe injury or disease of the left side of the palate and the upper mandible, which had not affected the growth of the teeth.

MR. OLDFIELD THOMAS, F.R.S., F.Z.S., exhibited the skin and skull of a Viverrine Carnivore from Tonkin, which, externally, was remarkably like the Banded Civet (*Hemigalus hardwickei*), but whose skull and teeth proved to be completely different. It was proposed to be called

CHROTOGALE OWSTONI, gen. & sp. nn.

General coloration as in *Hemigalus hardwickei*. Skull with long muzzle as in *Eupleres*. Incisor teeth broad, spatulate,

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with long level cutting-edges instead of points, their series above forming nearly a half-circle. Cheek-teeth proportionally small.

Hab. Tonkin.

Type. Young male. Original number 11.

Mr. Thomas at the same time proposed to distinguish "*Hemigale*" *hosei*, described by him in 1892, as a special genus to be called

DIPLOGALE, gen. n.

Pattern of coloration normal, not banded.

Skull with parallel-sided, square-fronted muzzle, the tooth-rows nearly parallel. P^1 with double root.

Type. *Diplogale hosei* (*Hemigale hosei*, Thos.).

Mr. GUY DOLLMAN exhibited a Monkey, belonging to the rare genus *Rhinopithecus*, from Tonkin, which he considered to represent a new species and proposed to call

RHINOPITHECUS AVUNCULUS, sp. n.

Size smaller than in *R. bieti*, M.-Edw.; tail longer.

Colour of dorsal surface black, underparts yellowish buff; tail black overlaid with yellowish white, terminal tuft white.

Dimensions of type:—

Head and body 520 mm.; tail 660; hind foot 165; ear 40.

Skull: greatest length 109 mm.

Hab. Yen-bay, Tonkin.

Type. Adult female. Original number 8.

Mr. A. RADCLIFFE DUGMORE, F.R.G.S., gave a lantern exhibition of a large number of photographic studies of wild animals in British East Africa and Newfoundland. This very beautiful series of pictures was briefly described by Mr. Dugmore, who dwelt particularly on the advantage to be gained by hunting with the camera, and showed that it was a sport as well as a means of securing interesting and valuable material.

Mr. EDWARD W. SHANN, B.Sc., read a paper, communicated by Prof. S. J. Hickson, D.Sc., F.R.S., F.Z.S., entitled "Observations on some Alcyonaria from Singapore, with a brief Discussion on the Classification of the Family Nephthyidæ." This collection was made by Mr. W. F. Lanchester and the late Mr. F. P. Bedford during their residence in Singapore. All the specimens had been obtained in shallow water, from low water-mark to a depth of about 10 fathoms, and of the eleven species dealt with in this paper, representing six different families, four were described as new. A brief historical summary of the genera *Nephthya*, *Dendronephthya*, and *Stereonephthya* was given, together with the author's reasons for retaining the definitions of these genera

of Nephthyidæ as enunciated by Prof. W. Kükenthal in his 'Revision of the Alecyonaria.' Among the illustrations were reproductions of some of Savigny's figures of his genera *Ammothée* and *Nephthée*.

Sir GEORGE H. KENRICK, F.Z.S., presented a paper entitled "A List of Moths of the Family Pyralidæ collected by Felix B. Pratt and Charles B. Pratt in Dutch New Guinea in 1909-10, with Descriptions of new Species."

Mr. T. H. WITHERS, F.G.S., read a paper, communicated by Dr. W. T. Calman, F.Z.S., on "Some early Fossil Cirripedes of the Genus *Scalpellum*."

Attention was drawn to the form of the carina of the geologically older species of *Scalpellum*, and it was shown that the earliest forms known resembled more closely the carina of *Pollicipes*, from which *Scalpellum* is considered to be derived. An almost complete capitulum of the Albian *Scalpellum arcuatum* was described, together with some scales of the peduncle, and a restoration was given. This specimen was important because, with the exception of a few detached valves found in the Aptian (Lower Greensand), it was the oldest-known fossil Cirripede that could with certainty be referred to the genus *Scalpellum*, *sensu lato*. *S. arcuatum* was considered to be an ancestral form of the group of almost exclusively deep-sea species, which Dr. P. P. C. Hoek had separated as a subgenus under the name *Arcoscalpellum*, and its relationship to other species was discussed. *S. trilineatum* was also re-described.

The next Meeting of the Society for Scientific Business will be held on Tuesday, April 2nd, 1912, at half-past Eight o'clock P.M., when the following communications will be made:—

1. EXHIBITIONS AND NOTICES.

2. D. SETH-SMITH, F.Z.S.

Lantern Exhibition of Nestling Cariamā, and the display of the Peacock Pheasant.

3. R. I. Pocock, F.R.S., F.L.S., F.Z.S.

On a rare Stag (*Cervus wallichii*) from Nepal, presented to the Society by H.M. The King. (With lantern illustrations.)

4. FRANK E. BEDDARD, M.A., F.R.S., F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidea.—IV. On Species of *Inermicapsifer* from the Hyrax and on the Genera *Zschokkeella*, *Thysanotania*, and *Hydracotania*.

5. DR. BASHFORD DEAN.

Additional Notes on the Living Specimens of the Australian Lung-Fish (*Ceratodus forsteri*) in the Collection of the Zoological Society of London.

The following papers have been received :—

1. JULIAN S. HUXLEY.

A First Account of the Courtship of the Redshank (*Totanus calidris*).

2. MRS. E. W. SEXTON.

Amphipoda from Bremerhaven.

3. C. TATE REGAN, M.A., F.Z.S.

Descriptions of new Fishes of the Family Loricariidæ in the British Museum Collection.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.

March 26th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

April 2nd, 1912.

Dr. A. SMITH WOODWARD, F.R.S., Vice-President,
in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

The SECRETARY read a Report on the Additions that had been made to the Society's Menagerie during the months of February and March 1912.

Dr. R. W. SHUFELDT, C.M.Z.S., sent for exhibition the skins of two young Virginia Opossums (*Didelphis virginiana*). These specimens were each about ten weeks old and belonged to the same litter.

The bones of the entire skeleton at this age were quite elementary in character, especially the terminal vertebræ of the tail, the bones of either carpus and those of the tarsi, and the epiphyses of the long bones, etc. The marsupial bones were well formed in both sexes, and upon either side were nearly as long as the corresponding ilium, and about one-fourth the size in bulk.

According to Flower, the number of vertebræ in the spine of the Virginia Opossum was 7 cervicals, 13 thoracic, 6 lumbar, and 26 caudals. This was probably correct for the adult animal of this species, while in subadults, of an age here considered, the last three caudals were not developed, and the three or four anterior to them were in the most rudimentary condition possible.

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In both these specimens the first dentition had perfectly erupted and was as follows:—

$$i \frac{5}{4}, \quad c \frac{1}{1}, \quad pm \frac{2}{2}, \quad m \frac{3}{3} = 42,$$

the formula for the adult being

$$i \frac{5}{4}, \quad c \frac{1}{1}, \quad pm \frac{3}{3}, \quad m \frac{4}{4} = 50.$$

The premolars were triangular, sharp-pointed, and flattened from side to side; the molars had numerous sharp cusps, and the canines were large and curved.

Mr. D. SETH-SMITH, F.Z.S., Curator of Birds, exhibited, by means of lantern-slides, photographs of the male Peacock Pheasant (*Polyplectron chinquis*) displaying to the female.

The typical display, as depicted in the photographs, resembled very closely that of the Argus Pheasant, the bird facing the female while he lowered the breast to the ground and expanded the wings and tail like a shield, the head being held sideways against one wing.

Mr. Seth-Smith also exhibited photographs of the young *Cariama cristata* hatched and reared in the Gardens in 1911, and remarked that although young of this species had been hatched in the Menagerie on previous occasions, he believed that this was the first occasion on which the young had been reared to maturity.

Mr. R. I. Pocock, F.R.S., F.L.S., F.Z.S., exhibited a lantern-slide of two Polar Bear cubs born in the Gardens in November 1911, and made some remarks upon the causes of the difficulty experienced in all Zoological Gardens in rearing the offspring of this species.

Mr. C. TATE REGAN, M.A., F.Z.S., exhibited some lantern-slides, prepared from photographs taken by Dr. F. B. Sumner, of a Mediterranean Flatfish (*Platophrys podas*) on sand, gravel, and various artificial backgrounds, showing its power of changing its colour and markings to resemble the ground on which it lies.

Mr. R. I. Pocock, F.R.S., F.L.S., F.Z.S., Superintendent of the Gardens, read a paper "On a rare Stag (*Cervus wallichii*) from Nepal, recently presented to the Zoological Society by His Majesty King George." The author pointed out the distinctive peculiarities of this species, which, on account of its great scarcity, had never been satisfactorily classified since it was described by G. Cuvier in 1825 from a coloured illustration of a specimen living at that time in the Barrackpore Menagerie. Some authors had supposed this Stag to be identical with the Kashmir species, or Hangul (*Cervus hanglu*); others had referred it to the Chumbi Valley species, or Shou (*Cervus affinis*). From both of these, however, it differed in having the rump-patch of large size, extending, that is to say, nearly to the summit of the croup, and

showing no trace of a dark median line dividing it into a right and left portion. Nevertheless, with respect to the size of the rump-patch and the distinctness and width of this divisional line, the Shou (*C. affinis*) seemed to be intermediate between the Hangul (*C. hanglu*) and Wallich's Stag (*C. wallichii*). In certain other respects, such as the colour of the lips, the length of the head, and the coarseness of the hair, *C. affinis* and *C. wallichii* were more like one another than either was like *C. hanglu*, and the evidence tended to show that the two former were subspecies of a species for which *wallichii* was the oldest available name.

MR. F. E. BEDDARD, M.A., F.R.S., F.L.S., Prosector to the Society, read a paper on species of Tapeworms of the genus *Inermicapsifer* obtained from the Hyrax, with notes on the genera *Zschokkeella* and *Thysanotania*. An account of the structure and characters of the species was given, together with the description of a new genus and two new species.

DR. BASHFORD DEAN contributed an account of the living specimens of the Australian Lung-fish (*Ceratodus forsteri*) in the Society's Collection. This paper contained some further observations made by the author in June 1911, supplementary to his previous communication published in 1906, and dealt with the coloration, size, and age of the specimens. Details of the rate of growth of this species were also given, with notes on their method of breathing, their food, and an account of the regeneration of a portion of the left ventral fin which had suffered an injury.

The next Meeting of the Society for Scientific Business will be held on Tuesday, April 23rd, 1912, at half-past Eight o'clock P.M., when the following communications will be made :—

1. EXHIBITIONS AND NOTICES.

2. JULIAN S. HUXLEY.

A First Account of the Courtship of the Redshank (*Totanus calidris*).

3. MRS. E. W. SEXTON.

Amphipoda from Bremerhaven.

4. C. TATE REGAN, M.A., F.Z.S.

Descriptions of new Fishes of the Family Loricariidæ in the British Museum Collection.

5. CHARLES H. O'DONOGHUE, B.Sc., F.Z.S.

The Circulatory System of the Common Grass-Snake (*Tropidonotus natrix*).

The following papers have been received:—

1. Major J. STEVENSON HAMILTON, C.M.Z.S.

The Local Races of Burchell's Zebra.

2. ROWLAND E. TURNER, F.Z.S., F.E.S.

Studies in the Fossorial Wasps of the Family Scoliidæ, Sub-families Elidinae and Anthoboscinae.

3. G. A. BOULENGER, F.R.S., F.Z.S.

On a Collection of Fishes made by Mr. A. Blayney Percival in British East Africa to the East of Lake Baringo.

4. FRANK E. BEDDARD, M.A., F.R.S., F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidea.—V. On a new Genus from the Tasmanian Devil (*Dasyurus ursinus*), the Type of a new Family.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.

April 9th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*
April 23rd, 1912.

Dr. S. F. HARMER, F.R.S., Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

The SECRETARY exhibited a living specimen of a young female Dorsal Hyrax (*Dendrohyrax dorsalis*) from Nigeria, recently presented to the Society by Mr. J. L. McKellar.

The SECRETARY exhibited a number of photographs of an Elephant Kraal in Siam which had been presented to the Society by the Rt. Hon. Sir Cecil Clementi Smith, P.C., G.C.M.G.

Mr. C. H. O'DONOGHUE, B.Sc., F.Z.S., read a paper on the Circulatory System of the Common Grass-Snake (*Tropidonotus natrix*). Several interesting features correlated with the loss of limbs and the elongation of the body were stated to occur in the blood-vessels. The vessels, like the viscera they supplied, were asymmetrical; not only were those on the right anterior to those on the left, but they were also noticeably larger. No indication of the descent of snakes from a limb-bearing ancestry was to be found in the circulatory system, save perhaps a small pair of veins which might correspond to the pelvic veins in *Lacertilia*. There was a marked tendency for the vessels to form longitudinal systems, *e. g.*, the arteries supplying the gut and the fat-bodies; and each ovarian artery formed a longitudinal trunk along the corresponding supra-renal body. The hepatic portal vein arose by two roots, one from each renal portal vein, and ran the whole length of the gut up to the liver. By the side of each oviduct

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was a conspicuous oviducal sinus, a vessel which had not been described previously in snakes.

The right carotid artery was not present in the adult, and to compensate for this the left side of the head received its arterial blood by means of three anastomoses—one beneath the medulla oblongata, one beneath the fore-brain, and one beneath the symphysis of the lower jaw. The part of the anterior cardinal vein in the head of the embryo was completely replaced during development by a new vessel, the lateral cephalic vein.

MR. JULIAN S. HUXLEY read a paper, communicated by Prof. G. C. BOURNE, D.Sc., F.R.S., F.Z.S., containing an account of the Courtship of the Redshank (*Totanus calidris*).

The first purpose of this paper was to draw attention to the many valuable results to be obtained by simple watching of very common British birds; and the second was to show how the facts observed in the Redshank bore on the theory of Sexual Selection. In this species there was no rival display between several males at once: a single female was courted by a single male, as in Man. The courtship started with a pursuit, the hen running in a circuitous course, followed by the cock. The pursuit was followed by a display, but only if the hen were willing that the courtship should continue. During display the cock uttered a special note, spread his tail, raised his wings above his back, and advanced with a curious high-stepping action towards the now stationary female. If the female so wished, pairing followed the display. But in quite 90 per cent. of observed courtships the female rejected the male, either during the pursuit or during the display, by simply flying away, when the cock was quite powerless to enforce his desires. Thus the consent of the hen was absolutely necessary if pairing were to take place, and this consent was usually withheld: in other words, selection by the female was a reality in the Redshank.

Other interesting points were as follows:—The plumage of the two sexes was identical, and was decidedly cryptic when the birds were at rest. During flight the white underside of the wings and the white tail were conspicuously revealed, and probably served as recognition marks. The significance of the red legs was unknown. During display the male drew attention to the underside of the wings by raising and vibrating them, to the tail by fanning it out, and to the red legs by his slow, high steps; besides this he uttered a note heard at no other time. Thus, since the actual colours and structures used in display were found in both sexes, the only peculiarly male possession—the only secondary sexual character of the Redshank—was a special behaviour, devoted to showing off these common colours and structures in a special way.

This seemed to show that secondary sexual differences in birds were originally differences of behaviour, and that only when these were established did differences of colour and structure come to be developed.

Mrs. E. W. SEXTON contributed a paper, communicated by the Rev. T. R. R. Stebbing, M.A., F.R.S., F.Z.S., based on a small collection of brackish-water Amphipoda from Bremerhaven. Special reference was made to a new species of *Gammarus*, which inhabited both fresh and brackish water, and was interesting as showing in a marked manner the effects of environment on development.

Mr. C. TATE REGAN, M.A., F.Z.S., read a paper containing descriptions of ten new species of South American Fishes of the Family Loricariidae in the British Museum Collection.

The next Meeting of the Society for Scientific Business will be held on Tuesday, May 7th, 1912, at half-past Eight o'clock P.M., when the following communications will be made:—

1. NOTICES AND EXHIBITIONS.

2. FRANCIS WARD, M.D., F.Z.S.

Lantern and Kinematograph Demonstrations of Photographs of Fishes and Aquatic Animals in Natural Illumination.

3. G. A. BOULENGER, F.R.S., F.Z.S.

On a Collection of Fishes made by Mr. A. Blayney Percival in British East Africa to the East of Lake Baringo.

4. ROWLAND E. TURNER, F.Z.S., F.E.S.

Studies in the Fossorial Wasps of the Family Scoliidae, Sub-families Elidinae and Anthoboscinae.

5. ABEL CHAPMAN, F.Z.S.

Notes on the Spanish Ibex.

The following papers have been received:—

1. Major J. STEVENSON HAMILTON, C.M.Z.S.

The Local Races of Burchell's Zebra.

2. FRANK E. BEDDARD, M.A., F.R.S., F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidea.—V. On a new Genus from the Tasmanian Devil (*Dasyurus ursinus*), the Type of a new Family.

3. WILLIAM NICOLL, D.Sc., F.Z.S.

On two new Larval Trematodes from the Striped Snake.

4. W. T. CALMAN, D.Sc., F.Z.S.

On *Dipteropeltis*, a new Genus of the Crustacean Order Branchiura.

5. SIR CHARLES ELIOT, K.C.M.G., C.B., F.Z.S.

A Note on the rare British Nudibranch *Hancockia eudactylota* Gosse.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,
Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.
April 30th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

May 7th, 1912.

Prof. E. A. MINCHIN, F.R.S., Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

Mr. R. I. Pocock, F.R.S., F.L.S., F.Z.S., Superintendent of the Gardens, exhibited a skin and a living specimen of a fawn variety of the Brown Rat (*Epinys norvegicus*), which had been caught on an island in the middle of Loch Corrib, Co. Galway, and presented to the Society by Lord Headley. Mr. Pocock remarked that although similarly coloured varieties of this rat had been caught now and again in different parts of England, it was especially interesting to put on record Lord Headley's statement that it was quite common on the island, no fewer than eleven having been trapped while others had been seen; and that it did not occur, so far as was known, on the mainland. Typically coloured brown rats lived on the island as well.

Mr. D. SETH-SMITH, Curator of Birds, exhibited two horn-like sheaths which had been shed from the orange-coloured patch at the base of the lower mandible of the King Penguin (*Aptenodytes pennanti*) living in the Society's Gardens. Mr. W. E. de Winton had observed the shedding of this epidermal sheath in a bird living in the Gardens in 1898 (P. Z. S. 1898, p. 900); but although the present specimen had been carefully watched during two successive moults in March and October 1911 (P. Z. S. 1912, p. 60), no sign of

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this process was observed. The bird, however, went through another complete moult in March to April of the present year (1912), and shortly after this was completed the epidermal covering of these orange-coloured patches became loose and finally fell off; the pieces somewhat resembled the wing-cases of a large beetle, being semi-transparent and of a clear orange-colour.

Dr. FRANCIS WARD, F.Z.S., showed a number of photographs and diagrams illustrating a method of observation of fishes, birds, and mammals under the water, the principle being that the subjects under consideration were illuminated by natural light, and the observer being in a dark chamber in the water was not seen. The appearance of black-feathered birds was shown; these, by carrying down air-bubbles among the feathers, were converted into reflectors: and a Water-Hen was shown bright red and then green as it reflected the different surroundings in which it had been placed. Otters and Seals were also shown as seen under the water. The demonstration was illustrated by numerous slides and by the cinematograph.

Mr. G. A. BOULENGER, F.R.S., F.Z.S., presented a paper on a collection of Fishes made by Mr. A. Blayney Percival in British East Africa to the east of Lake Baringo. This collection was of special importance as coming from a district the fishes of which had not been collected before, and contained examples of five new species.

Dr. F. E. BEDDARD, M.A., F.R.S., F.Z.S., Prosector to the Society, gave an account of his paper on a new Genus of the Cestoidea, founded on some specimens of Tapeworms which he had discovered in the small intestine of an example of the Tasmanian Devil (*Dasyurus ursinus*). In briefly describing the most salient points of anatomical interest in this form, which formed the type of a new Family, he remarked that in view of the very considerable peculiarities of structure observed it was remarkable that the generative organs did not show any marked features of interest as compared with those of other Tapeworms.

Mr. R. E. TURNER, F.Z.S., F.E.S., communicated a memoir entitled "Studies in the Fossorial Wasps of the Family Scoliidae, Subfamilies Elidinae and Anthoboscinae." Several new species of Elidinae from South Africa were described, including a new genus in which the female was wingless, and the genus *Anthobosca* was monographed. The geographical distribution of *Anthobosca*, which was almost entirely confined to the Southern Hemisphere, was discussed, and the conclusion was reached that the distribution was due to survival from a wider range in the past, and not to a southern origin.

Mr. ABEL CHAPMAN, F.Z.S., contributed a short paper containing some notes on the Spanish Ibex, with reference to Prof. Angel Cabrera's recent paper on this species.

The next Meeting of the Society for Scientific Business will be held on Tuesday, May 21st, 1912, at half-past Eight o'clock P.M., when the following communications will be made:—

1. A. BLAYNEY PERCIVAL, F.Z.S.

Lantern Exhibition of Game Animals from British East Africa.

2. Major J. STEVENSON HAMILTON, C.M.Z.S.

The Local Races of Burchell's Zebra.

3. WILLIAM NICOLL, D.Sc., F.Z.S.

On two new Larval Trematodes from the Striped Snake.

4. W. T. CALMAN, D.Sc., F.Z.S.

On *Dipteropeltis*, a new Genus of the Crustacean Order Branchiura.

5. G. A. BOULENGER, F.R.S., F.Z.S.

Second Contribution to our Knowledge of the Varieties of the Wall-Lizard (*Lacerta muralis*).

6. Sir CHARLES ELIOT, K.C.M.G., C.B., F.Z.S.

A Note on the rare British Nudibranch *Hancockia eudactylota* Gosse.

The following papers have been received:—

1. R. LYDEKKER, F.R.S., F.Z.S.

The North Rhodesian Giraffe.

2. Prof. S. J. HICKSON, F.R.S., F.Z.S.

On the Hydrocoralline Genus *Errina*.

3. FRANK E. BEDDARD, M.A., D.Sc., F.R.S. F.Z.S.

Contributions to the Anatomy and Systematic Arrangement of the Cestoidea.—VI. On an Asexual Tapeworm from the Rodent *Fiber zibethicus*, showing a new form of Asexual Propagation, and on the supposed Sexual form.

4. HELEN L. M. PIXELL, B.Sc., F.Z.S.

Polychæta from the Pacific Coast of North America.—Part I. Serpulidæ, with a Revised Table of Classification of the Genus *Spirorbis*.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.

May 14th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*
May 21st, 1912.

Sir EDMUND G. LODER, Bt., Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

The SECRETARY read a report on the Additions that had been made to the Society's Menagerie during the month of April 1912.

Mr. A. BLAYNEY PERCIVAL, F.Z.S., exhibited a number of photographs and lantern-slides of Game Animals from British East Africa, including a fine series of the Reticulated Giraffe.

Mr. D. SETH-SMITH, F.Z.S., Curator of Birds, exhibited two living specimens of a rare Lory, *Calliptilus solitarius*, from Fiji, and remarked that Dr. Philip H. Bahr had recently brought home two specimens which had died. The specimens exhibited were from a collection of eight brought home alive by Mr. Rood Tarte, of Taviuni Island, one of the Fijian group, where this very beautiful species was still abundant, its numbers having been very considerably reduced in the other islands by the introduced mongoose. The exhibitor referred to a recent note on the species by Dr. Bahr in 'The Ibis' for April 1912, p. 293.

Major J. STEVENSON HAMILTON, C.M.Z.S., the Game Warden of the Transvaal, communicated a short paper, illustrated by photographs, on the local races of Burchell's Zebra, and pointed out that it was possible to shoot in one herd individuals presenting the characters of various subspecies as described by systematists. In the Transvaal, for example, he obtained skins exhibiting features claimed to be distinctive of such races as *E. burchelli wahlbergi*, *E. b. transvaalensis*, and *E. b. chapmani*; and from his experience

* This Abstract is published by the Society at its offices, Zoological Gardens, Regent's Park, N.W., on the Tuesday following the date of Meeting to which it refers. It will be issued, along with the 'Proceedings,' free of extra charge, to all Fellows who subscribe to the Publications; but it may be obtained on the day of publication at the price of *Sixpence*, or, if desired, sent post-free for the sum of *Six Shillings* per annum, payable in advance.

he expressed the opinion that these subspecies had been based upon inadequate museum material.

Dr. WILLIAM NICOLL, F.Z.S., communicated some observations on two new Trematode larvæ found encysted in enormous numbers in the mesentery of several Striped Snakes (*Tropidonotus ordinatus sirtalis*) which had died in the Society's Gardens. He named these forms, as neither could be referred to any adult species already known. It could be safely predicted, however, that the second species completed its life-cycle in the intestine of a bird, and from this fact it could be inferred that the Striped Snake was eaten by birds.

Dr. W. T. CALMAN, F.Z.S., read a short paper describing a new genus and species of the Crustacean Order Branchiura.

A parasite of fishes collected by Spencer Moore, Esq., at Corumba, Matto Grosso, Southern Brazil, was referred to a new genus as follows:—

DIPTEROPELTIS, gen. n.

Differing from *Argulus* in having no spine on the preoral papilla; in having the antennules and antennæ very minute and imperfectly segmented; in having no large spines or hooks on the under surface of the carapace, body, or appendages; in having no furcal rami on the abdomen; and in having the lateral wings of the carapace greatly elongated.

Genotype, *D. hirundo*, sp. n., with the characters of the genus.

Mr. G. A. BOULENGER, F.R.S., F.Z.S., read a paper entitled "Second Contribution to our Knowledge of the Varieties of the Wall-Lizard." This paper was a continuation of one published in the Society's 'Transactions' in 1905, and dealt chiefly with the variations of *Lacerta muralis* in South-Eastern Europe and South-Western Asia. It also contained a supplement to the first part, thus completing an account of the varieties, of which about thirty were regarded as more or less definable, the author endeavouring to show the inconstancy of the characters adduced by some herpetologists in assigning specific rank to a number of these forms, connected by many gradations. Mr. Boulenger hoped to support his statements by a number of photographic figures of specimens selected out of the enormous material which had passed through his hands in the course of his study of this polymorphic and widely distributed lizard.

This paper will be published in the 'Transactions' in due course.

A short note on the rare British Nudibranch *Hancockia eudactylota* Gosse was received from Sir Charles Eliot, K.C.M.G.,

C.B., F.Z.S., with some coloured figures of a single specimen captured at Plymouth. These were of special interest, as no coloured figure of this species had yet been published.

The next Meeting of the Society for Scientific Business (closing the Session 1911-1912) will be held on Tuesday, June 4th, 1912, at half-past Eight o'clock P.M., when the following communications will be made :—

1. E. G. B. MEADE-WALDO, V.P.Z.S. will introduce a discussion
on the Preservation of the English Fauna.
2. R. LYDEKKER, F.R.S., F.Z.S.
The North Rhodesian Giraffe.
3. Prof. S. J. HICKSON, F.R.S., F.Z.S.
On the Hydrocoralline Genus *Errina*.
4. FRANK E. BEDDARD, M.A., D.Sc., F.R.S., F.Z.S.
Contributions to the Anatomy and Systematic Arrangement
of the Cestoidea.—VI. On an Asexual Tapeworm from the
Rodent *Fiber zibethicus*, showing a new form of Asexual
Propagation, and on the supposed Sexual form.
5. HELEN L. M. PIXELL, B.Sc., F.Z.S.
Polychæta from the Pacific Coast of North America.—Part I.
Serpulidæ, with a Revised Table of Classification of the Genus
Spirorbis.
6. R. BROOM, D.Sc., C.M.Z.S.
On some new Fossil Reptiles from the Permian and Triassic
Beds of South Africa.

The following papers have been received :—

1. E. DUKINFELD JONES, F.Z.S., F.E.S.
Descriptions of new Butterflies of the Genus *Thecla* from
S.E. Brazil.

2. T. P. BUIST, M.A., B.Sc.

On the Development of the Pectoral Girdle in the Pipe-fish
(*Syngnathus acus*).

3. F. F. LAIDLAW, F.Z.S.

Some Notes on Bornean Dragonflies, with Descriptions of
New Species.

Communications intended for the Scientific Meetings should
be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.

May 28th, 1912.

ABSTRACT OF THE PROCEEDINGS
OF THE
ZOOLOGICAL SOCIETY OF LONDON.*

June 4th, 1912.

E. G. B. MEADE-WALDO, Esq., Vice-President, in the Chair.

The Minutes of the last Scientific Meeting were confirmed.

MR. E. G. BOULENGER, Curator of Reptiles, exhibited a clay-ball containing a cocoon of the African Lung-fish (*Protopterus annectens*) presented to the Society by Capt. J. A. M. Vipan, F.Z.S. He briefly alluded to the habits of the fish and the formation of the cocoon, and gave an account of the method to be employed in order to release the fish.

The Preservation of the Native Fauna of Great Britain.

MR. E. G. B. MEADE-WALDO, Vice-President of the Society, introduced a discussion on the Preservation of our Native Fauna, in which Mr. A. Heneage Cocks, Dr. F. G. Dawtrey Drewitt, and Mr. Stewart Blakeney (who sent a written contribution) joined. The necessity of creating public opinion on the matter was urged. It was agreed that the laws with regard to birds were sufficient, if administered strictly. With regard to mammals, it was the opinion of those present that the use of steel traps, instead of snares, for catching rabbits was chiefly responsible for the extermination of wild cats, martens, and polecats in many parts of the country, and ought to be suppressed.

MR. R. LYDEKKER, F.R.S., F.Z.S., communicated a short paper describing a new local race of Giraffe from the Petauke district of North-east Rhodesia.

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MISS HELEN L. M. PIRELL, B.Sc., F.Z.S., read a memoir entitled "Polychæta from the Pacific Coast of North America. Part I." This paper contained a description of Serpulidæ from the Straits of Georgia, chiefly the Departure Bay region of Vancouver Island, together with some specimens from Victoria and Puget Sound, eighteen species in all, of which five were new. *Serpula splendens* (Bush, 1905) was shown to be identical with *Serpula columbiana* (Johnson, 1901); and Caullery and Mesnil's classification of the genus *Spirorbis* was revised and enlarged to contain three new species and such other Pacific species as had been adequately described. Further evidence was given in support of the suggestion made by Caullery & Mesnil in 1897 that *Spirorbis* (*Circeis*) *armoricana* (St. Joseph, 1894) was only a variety of *Spirorbis spirillum* (Linné, 1760).

MR. R. I. POCKOCK, F.R.S., F.Z.S., Curator of Mammals, read a paper, illustrated by lantern-slides, on antler growth in the Cervidæ with special reference to *Elaphurus* and *Dorcelaphus*, and pointed out that the growth of the individual antler in *Elaphurus*, as shown by a series of sketches kindly supplied by Lord Tavistock, proved that the anterior and posterior branches of the antler of *Elaphurus* were homologous with the brow-tine and beam of the Sambar's antler, and that in *Dorcelaphus* the sub-basal snag was the homologue of the brow-tine in the Old World deer as Sir Victor Brooke claimed.

DR. HANS GADOW, F.R.S., F.Z.S., read a paper on "The One-sided Reduction of Ovaries and Oviducts in the Amniota, with remarks on Mammalian Evolution." He stated that the reduction began with the oviduct, and a first cause of the invariably right-sided bias had to be looked for in the turning of the embryo upon its left side, a position which influenced the growth and relative position of the stomach and primary intestinal loops, these being stowed in the abdomen in such a way that they were less disturbed by an egg passing through the left than through the right oviduct. In the Monotremes also only the left ovary and duct were functional, although those of the right side were structurally not affected. This was not a case of reptilian inheritance. Proto- Meta- and Eutheria represented a continuous, monophyletic line of evolution, with the Monotremes and Marsupials as offshoots. The Metatherian stage was diphyodont, marsupiate and placental. It was the parting of the ways. Those which developed a corpus callosum, correlated with higher mental faculties by further improving the placentation, and losing the marsupium (not the bursæ), became Placentalia; whilst the remaining stock, being driven to arboreal life, intensified the marsupial and thereby diminished the uterine gestation. Their arborealism implied the necessity of taking their young with them.

When Eutheria took to arboreal life the chance of reviving the lost marsupium was gone, nor did their higher mental and placental organization require it.

Dr. F. E. BEDDARD, M.A., F.R.S., F.Z.S., gave an account of an asexual Tapeworm, obtained from the Musquash (*Fiber zibethicus*), showing a new form of asexual propagation, and also described a sexual worm which he believed to be the mature form of the same Tapeworm.

Dr. WILLIAM NICOLL, F.Z.S., described two new Trematode parasites from the Indian Cobra (*Naja tripudians*). The first was found in the gall-bladder and was made the type of a new genus of the family Dicrocoeliidæ. The second was found in the ureters and represented a new species of the genus *Styphlodora*. Dr. Nicoll also gave statistics of the Worm Parasites collected from the animals which had died in the Society's Gardens during the period from December 1910 till April 1912.

Dr. R. BROOM, C.M.Z.S., presented a paper based on some new Fossil Reptiles from the Permian and Triassic Beds of South Africa.

Prof. S. J. HICKSON, F.R.S., F.Z.S., communicated a paper on the Hydrocoralline genus *Errina*. This genus was founded by Gray in 1835, and since that date two other genera (*Labiopora* and *Spinipora*) closely related to *Errina* had been described. An analysis of the characters of these three genera was given. An examination of Gray's type of *Errina* proved that it was more closely related to the species referred by Moseley and others to the genus *Labiopora*, than to the species referred by them to the genus *Errina*. The author proposed, therefore, to merge the three genera into one with the common generic name *Errina*, dividing the species into three subgeneric groups. Two new species were described, one from New Zealand waters and the other from the Cape of Good Hope.

This Meeting closes the Session 1911-1912. The next Meeting of the Society for Scientific Business will be held on Tuesday, October 29th, 1912, at half-past Eight o'clock P.M.

The following papers have been received :—

1. E. DUKINFIELD JONES, F.Z.S., F.E.S.

Descriptions of new Butterflies of the Genus *Thecla* from S.E. Brazil.

2. F. F. LAIDLAW, F.Z.S.

Some Notes on Bornean Dragonflies, with Descriptions of New Species.

Communications intended for the Scientific Meetings should be addressed to

P. CHALMERS MITCHELL,

Secretary.

ZOOLOGICAL SOCIETY OF LONDON,
REGENT'S PARK, LONDON, N.W.
June 11th, 1912.

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NOTICE.

The 'Proceedings' for the year are issued in *four* parts, paged consecutively, so that the complete reference is now P. Z. S. 1912, p. . . . The Distribution is as follows:—

Part	I.	issued in March.
"	II.	" June.
"	III.	" September.
"	IV.	" December.

'Proceedings,' 1912, Part I. (pp. 1-240), were published on March 13th, 1912.

'The Abstracts of the Proceedings,' Nos. 106 to 111 are contained in this Part.

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